Air Quality, Oil Shale, and Wilderness — A Workshop to Identify and Protect Air Quality Related Values of the Flat Tops

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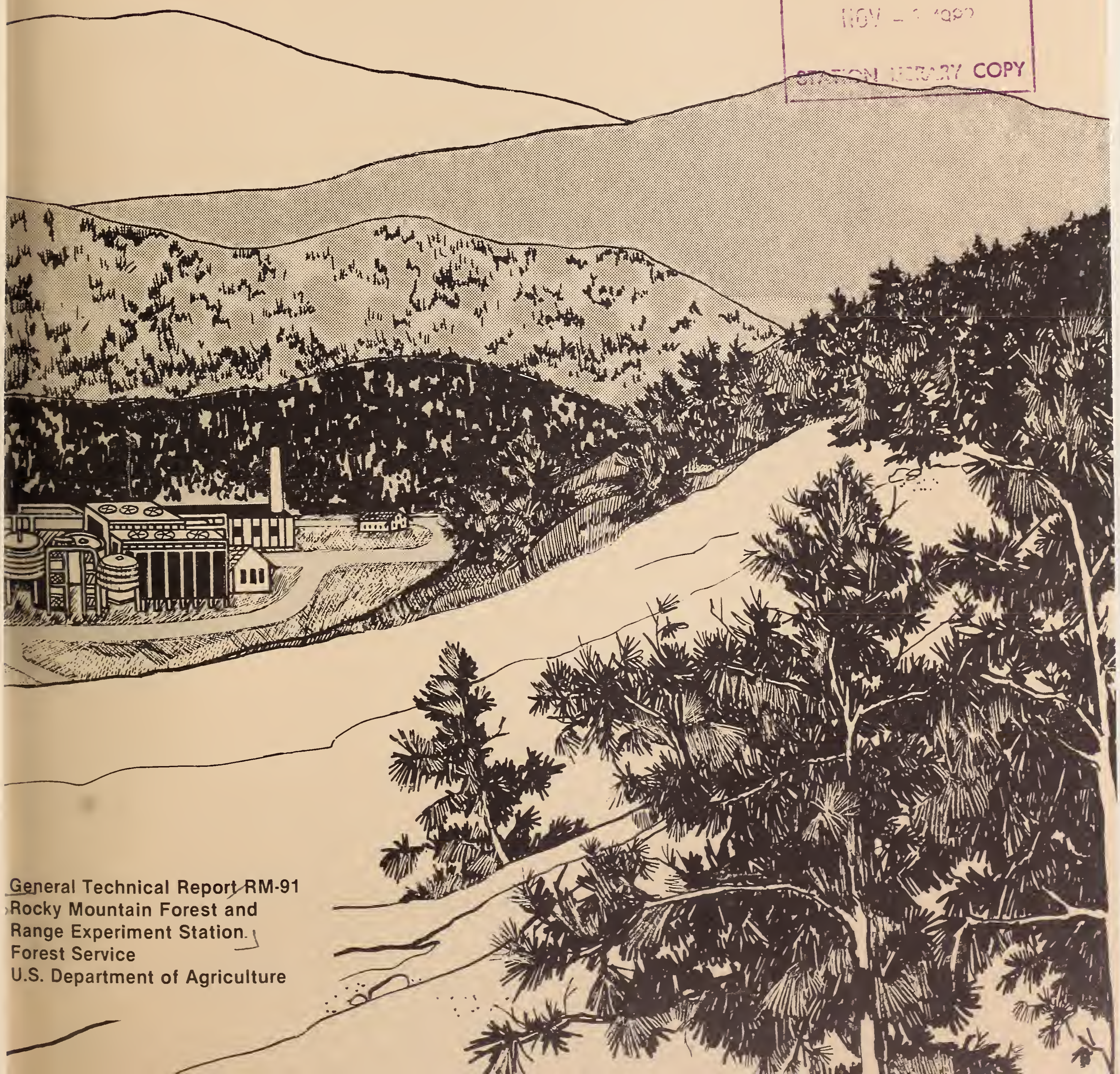
Glenwood Springs, Colorado

Douglas G. Fox, Dennis J. Murphy, and Dennis Haddow
Technical Coordinators



General Technical Report RM-91
Rocky Mountain Forest and Range Experiment Station
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Abstract

In January 1981, a workshop was conducted to discuss the potential impacts of oil shale developments on the air quality of western Colorado. Participants of the workshop included nationally recognized specialists in air quality modeling, in visibility, and in effects of air pollution on soil and water, fish and wildlife, and vegetation. The five working group reports that resulted outline an ambitious program of research necessary in order to protect the Flat Tops Wilderness. The workshop illustrates a general approach to the problem of identifying air quality related values. It is anticipated that this approach will prove useful to all federal land managers involved with Class I area protection.

USDA Forest Service

General Technical Report RM-91

September 1982

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Douglas G. Fox,[1] Dennis J. Murphy,[1] and Dennis Haddow[2]

Technical Coordinators

Jointly sponsored by
U.S. Forest Service, Rocky Mountain Region
White River National Forest
Rocky Mountain Forest and Range Experiment Station

[1]USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, in cooperation with Colorado State University.

[2]USDA Forest Service, Rocky Mountain Region (Region 2), Lakewood, Colorado.

PREFACE

The 1977 Amendments to the Clean Air Act established a new air quality program charged with maintaining clean air in those parts of the country where the air is currently cleaner than that required to protect public health. This Prevention of Significant Deterioration (PSD) program established Class I areas and gave the federal land manager a primary role in reviewing new pollution sources to ensure that "air quality related values" (AQRV's) are not adversely impacted.

There is considerable uncertainty associated with determining precisely what constitutes an adverse impact on air quality values. It is clear from the Act, supporting regulations, and USDA Forest Service policy (FSM 2120) that AQRV's include, but are not limited to, visibility, flora, fauna, soil, water, and cultural characteristics of the Class I area. It is not clear what level of effect upon these values is to be judged adverse. At the present time, the Forest Service, both nationally and in the Rocky Mountain Region (Region 2), has no policy dealing with either the level at which an effect is adverse or the procedure by which a judgement on adversity should be made. As of September 1981, no adverse impact has ever been determined for any AQRV within any Forest Service-administered Class I area. It is, however, unlikely that this will continue indefinitely. There is a need to develop procedures that will allow rational evaluation of effects on AQRV's.

The Flat Tops Wilderness, located on the White River and Routt National Forests, is such a Class I area, and the Forest Service, therefore, must evaluate permits for new pollution sources relative to their potential impact on the area. Of the 88 Forest Service-administered, mandatory Class I areas throughout the United States, none is more likely to experience impacts than the Flat Tops. Coal mining and power generating facilities, increased mineral (uranium and others) activity, and the rapid upsurge in oil shale processing facilities have all been proposed essentially upwind and within a 50-mile radius of the Flat Tops.

The Forest Meteorology and Air Quality Unit of the Rocky Mountain Forest and Range Experiment Station is engaged in research to help develop tools and procedures to aid decisionmaking related to PSD permitting. A critical step in this decisionmaking involves the identification of, and evaluation of potential impacts upon wilderness AQRV's. At the same time, Region 2 of the Forest Service is facing similar operational needs associated most specifically with the Flat Tops Wilderness and oil shale development. For these reasons the Forest Service convened a workshop at Glenwood Springs, Colo., during January 1981. The participants included nationally recognized experts in air quality impacts on vegetation, fish and wildlife, water, and visibility, and specialists in each of these subjects from the Regional Office, the White River and the Routt National Forest staffs. The objective of the workshop was to identify those elements of the Flat Tops ecosystem most likely to experience any impact as a result of projected pollution increases. Secondly, having identified these most sensitive elements, the participants were asked to determine the extent of available information and to design studies to gather any data needed to evaluate the potential impact on the Flat Tops.

The outcome of this workshop should be of broad national interest for two reasons: It represents a first step in the PSD permitting process, illustrating one procedure through which AQRV's can be identified; and it provides an indication of the scientific magnitude of the task mandated to federal land managers by the Clean Air Act 1977 amendments. In addition, it should provide a preliminary indication for interested parties of the Flat Tops AQRV's.

This report summarizes the findings of the workshop. Major recommendations and conclusions are outlined in an executive summary. A brief overview of intended oil shale development and an outline of the Forest Service responsibilities follows. Finally, group reports are included to provide the backup information for the recommendations.

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INTRODUCTION

Oil shale projects lead the proposed development of energy resources in western Colorado. Figure 1 locates a group of proposed projects in relation to the Flat Tops Wilderness area (a mandatory Class I area administered by the USDA Forest Service). Since all of the Colorado developments are located within 100 km of the Flat Tops, they will each require a Prevention of Significant Deterioration (PSD) review of their impacts on the AQRV's of the Flat Tops. Table 1 provides a key to figure 1 and a listing of some of the projected developments. Table 2 shows the projected 1982 levels of emissions and the 1985 projections for some regulated pollutants. The various processes represent combinations of aboveground retorting and in situ combustion to drive off the oil from the shale thermally. Each process has somewhat different emission characteristics. For the purposes of this workshop, it is sufficient to consider the emission figures shown in table 2. Actual numbers will be different as specific processes develop.

In addition to the increase in emissions, the industrial development will lead to major influxes of people. Figure 2 illustrates one projection of population increase associated with the oil shale development.

The Forest Service, as the federal land manager for the Flat Tops Wilderness, has "an affirmative responsibility to protect air quality related

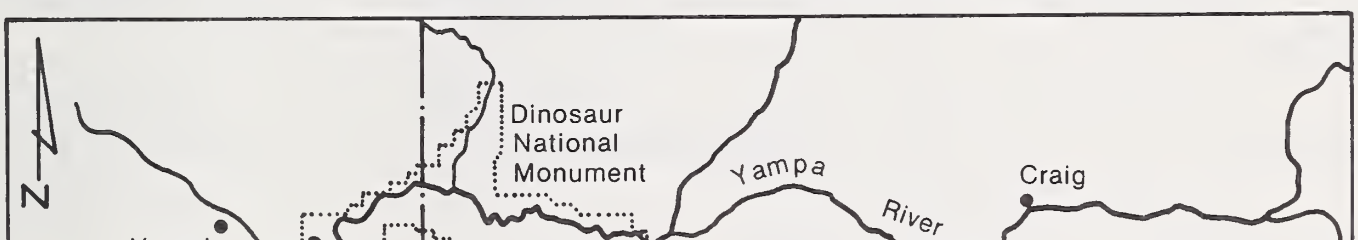

Figure 1.--Locations of proposed oil shale developments in Colorado and Utah.

Table 1.--Proposed oil shale development projects in Colorado and Utah[1]

Oil shale project Lease site (Operators)	Location[2]	Process	Production rate 1982	1985	1990	1995
			(barrels/day)			
Cathedral Bluffs Oil Shale Co. Lease Tract C-b (Occidentals, Tenneco)	A	38% Lurgi 62% MIS	--	30,000	100,000	100,000
Project Rio Blanco Lease Tract C-a Gulf, Standard (Indiana)	B	100% Lurgi	--	45,600	76,000	135,000
Geokinetics, Inc. Uinta Basin	C	Occidental MIS	5,000	15,000	50,000	50,000
Equity Oil Naval Oil Shale Reserve	D	Bx in-situ	--	--	--	--
Piceance Basin	E	Paraho	--	--	28,000	50,000
Union Oil/Long Ridge Piceance Basin	H	Union B	9,500	30,000	50,000	100,000
Colony/Tosco Parachute Creek Piceance Basin (Exxon, Tosco)	I	Tosco/Colony/Sand Wash	--	38,400	46,200	46,200
Tosco Sand Wash Uinta Basin	J	Tosco/Colony/Sand Wash	--	23,100	46,200	46,200
White River Project Lease site U-a, U-b (Phillips, Sohio, Sunoco)	K	Paraho	--	--	--	90,000
Chevron Oil Piceance Basin	L	Union B	--	15,600	66,600	100,000
Superior Oil Piceance Basin	M	Superior	--	6,700	12,000	12,000
Mobil Oil Piceance Basin	N	Union B	--	--	50,000	91,500
Carter Oil Piceance Basin	O	Union B	--	--	60,000	60,000
Cities Service	P	--	--	--	--	--
Total			14,500	204,400	585,000	880,900

[1]Source: Anderson, G. E., J. R. Doyle, D. A. Latimer, C. S. Liu, M. A. Wojcik, and J. A. Johnson. 1981. Air quality impacts of anticipated development in oil shale operations in western Colorado and eastern Utah. April 2, 1981. Report by Systems Application, Inc., San Rafael, Calif.

[2]Codes match with those of figure 1.

Table 2.--Projected oil shale processing emission rates in 1982 and 1985

Oil shale project	Location[1]	Process	Production capacity	Average emission rate (g/s) SO_2	NO_x	HC	TSP	CO
			1982					
Geokinetics, Inc. Uinta Basin	C	Occidental (MIS)	5,000	3.1	15.4	0.7	4.1	6.1
Union Oil Piceance Basin	H	Union (Union B)	9,500	14.6	18.3	16.8	5.0	11.3
Total			14,500	17.7	33.7	17.5	9.1	17.4
			1985					
Occidental Oil Tract C-b	A	Occidental (MIS)	30,000	18.2	92.5	3.9	24.6	30.7
Project Rio Blanco Track C-a	B	Rio Blanco	45,600	12.9	106.4	5.0	35.8	48.1
Geokinetics, Inc. Uinta Basin	C	Occidental (MIS)	15,000	9.1	46.2	2.0	12.3	18.4
Union Oil Piceance Basin	H	Union (Long Ridge)	30,000	46.1	57.7	52.9	15.9	35.8
Colony/TOSCO Parachute Creek	I	TOSCO II	38,400	31.7	216.8	38.9	59.1	7.0
TOSCO Uinta Basin	J	TOSCO II	23,100	19.1	130.4	23.4	35.6	4.2
Chevron Oil Piceance Basin	L	Union (Long Ridge)	15,600	24.0	30.0	27.5	8.3	18.6
Superior Oil	M	Superior	6,700	24.4	12.1	1.9	5.3	3.3
Total			204,400	185.5	692.1	155.5	196.9	172.1

[1]Codes match with those of figure 1.

values" of the area. This responsibility manifests itself through participation in the permit application and review process. For areas such as western Colorado, PSD provisions require that nowhere shall the Class II increments for sulfur dioxide (SO_2) and total suspended particulates (TSP) be exceeded; that best available control technology (BACT) applies; and that, in cooperation with the federal land manager, the Class I area (Flat Tops Wilderness) shall be protected from any adverse impact. This responsibility, while specifically identified by the Clean Air Act, is really not substantially different from the responsibilities granted under the Wilderness Act and the establishment legislation for most wilderness areas. The additional responsibility granted by the Clean Air Act merely provides authority to act and exert influences more directly.

The Environmental Protection Agency (EPA) and state regulatory agencies have technical

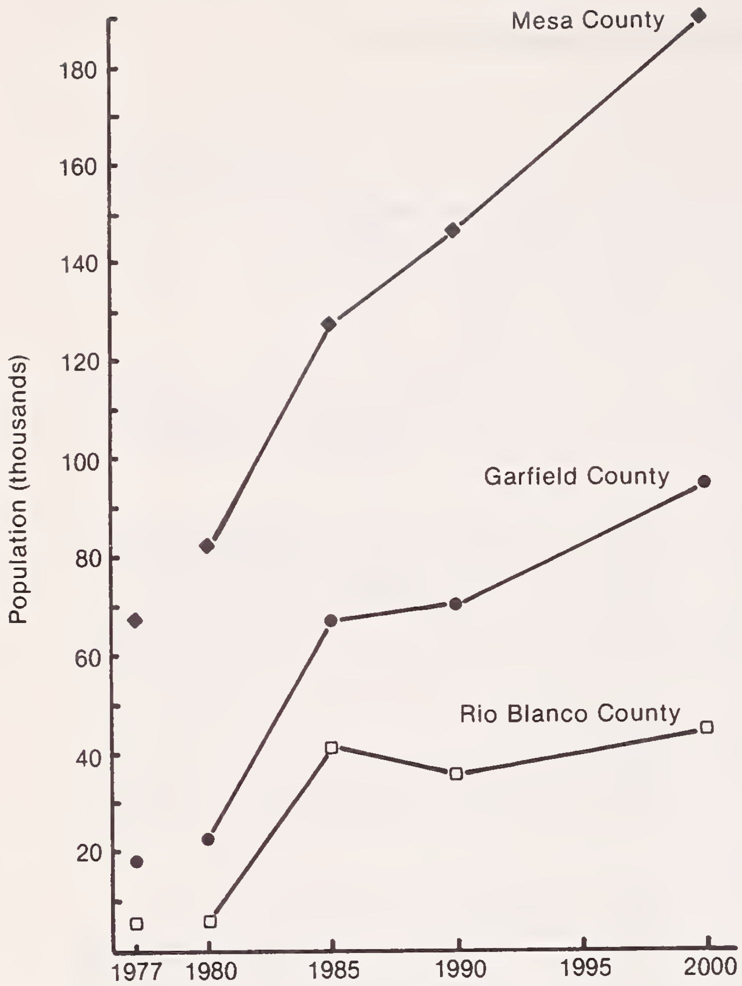

Figure 2.--Projected growth of counties in northwestern Colorado from oil shale development, 1980-2000.

1977--actual population from special U.S. census

1980-2000--projections assume oil shale development with a production level of 500,000 bpd by 1990 and 750,000 bpd by 1995 combined with other energy industry (e.g., coal, electric generation, oil, and gas) expansion

Source: Office of Technology Assessment (1980)

responsibilities for tasks such as tracking the consumption of the numerical increments and negotiating best available control technology. The federal land manager must evaluate biological and social impacts and determine if they are adverse or not. It is consistent with wilderness management responsibilities to protect these areas from any unauthorized human-caused impacts.

The Flat Tops Wilderness will potentially experience adverse impacts. It is, therefore, necessary to identify what the AQRV's of the Flat Tops are and at what levels of pollution the various values might experience an impact.

EXECUTIVE SUMMARY

Traditionally, regulatory agencies dealing with air quality have been responsible for monitoring pollutants, predicting future pollutant concentrations, and requiring various engineering controls to reduce emissions and, ultimately, the atmospheric concentration of pollutants. The Clean Air Act Amendments of 1977 additionally gave the federal land manager "an affirmative responsibility to protect the air quality related values of any such lands within a Class I area." This statement gives the USDA Forest Service a responsibility to determine the biological, physical, and visibility impacts of air quality degradation in the designated Class I wilderness area for which it is responsible.

A developing oil shale industry on the western slope of Colorado has a potential to impact the AQRV's of the Flat Tops Wilderness area adversely. As a result of increased activity in the oil shale industry, the USDA Forest Service, Rocky Mountain Region, and the Rocky Mountain Forest and Range Experiment Station, along with the White River National Forest, sponsored a workshop in Glenwood Springs, Colo., January 13-15, 1981, on air quality related values in the Flat Tops Wilderness area.

The meeting brought together scientists working in the areas of pollutant effects and local field personnel in an effort to assess the potential biological, physical, and visibility effects the oil shale industry would have on the Flat Tops and to consider monitoring and research needs.

Participants were divided into groups on visibility, soil and water, fish and wildlife, vegetation, and air quality modeling. Members of each group produced a report specific to their area of expertise; however, several common recommendations emerged. It was recognized by all groups that there must be a great deal of cooperation among industry, local and state agencies, and, especially, among federal agencies in the development of oil shale and protection of wilderness values. Also, all groups strongly recommended that air quality dosage models be developed for the area. The models are needed to assess potential pollutant concentrations in various areas of the Flat Tops Wilderness so that dosages to soil, vegetation, water, fish, and wildlife can be estimated. A modeling program will also be extremely important in designing cost-effective monitoring programs for biological and physical effects in the wilderness area.

Specific group recommendations are as follows:

1. Visibility: Proposed a long-term visibility monitoring program in the wilderness to measure current conditions, and future emissions of those pollutants that have a potential to degrade visibility. Also proposed studies of wilderness users to identify their perceptions of visibility impairment and its significance to them.

2. Soil/Water: Proposed monitoring the sensitive, poorly buffered, high lakes (i.e., Surprise, Upper Island, and Shingle) for any changes

in pH and nutrients. Additionally, the group proposed a modification to the current USDA Forest Service Flat Tops water monitoring program and suggested long-term monitoring of precipitation quality, soil chemistry, and lake chemistry.

3. Fish and Wildlife: Outlined a process to aid the USDA Forest Service in better identifying sensitive receptors in the Flat Tops. Several sensitive indicator species to the expected pollutants are cutthroat trout, beaver, elk, deer, white-crowned sparrow, pika, ptarmigan, and bees. A long-term monitoring program of these species was identified.

4. Vegetation: Suggested a two-stage monitoring program. The first stage would utilize the most sensitive plant species in the wilderness to alert the federal land manager that air pollutants are reaching the wilderness in potentially significant quantities. The second stage would involve monitoring the viability of key species of the general Flat Tops ecosystem. The first-stage indicators suggested were lichen and bryophytes to monitor sulfur dioxide (SO_2) and needle retention in spruce and fir to detect significant quantities of ozone (O_3).

5. Modeling/climate: Stressed the need for further research in atmospheric dispersion in complex terrain areas and in deposition and dosage models. Since the Flat Tops Wilderness is the first high ground directly downwind from the oil shale area, pollutants released during mining and processing are likely to be deposited by both dry and wet (precipitation) mechanisms. Dosage models are needed to identify and quantify potential impacts on vegetation, soil, water, fish, and wildlife. The modeling requirements are illustrated in figure 3. Use of models in complex terrain areas will also aid in the conduct of monitoring programs by locating areas and times of greatest potential impact.

The workshop (i.e., the results from it) should be viewed as an example of how AQRV's can be identified and of the magnitude of the task that faces federal land managers in providing

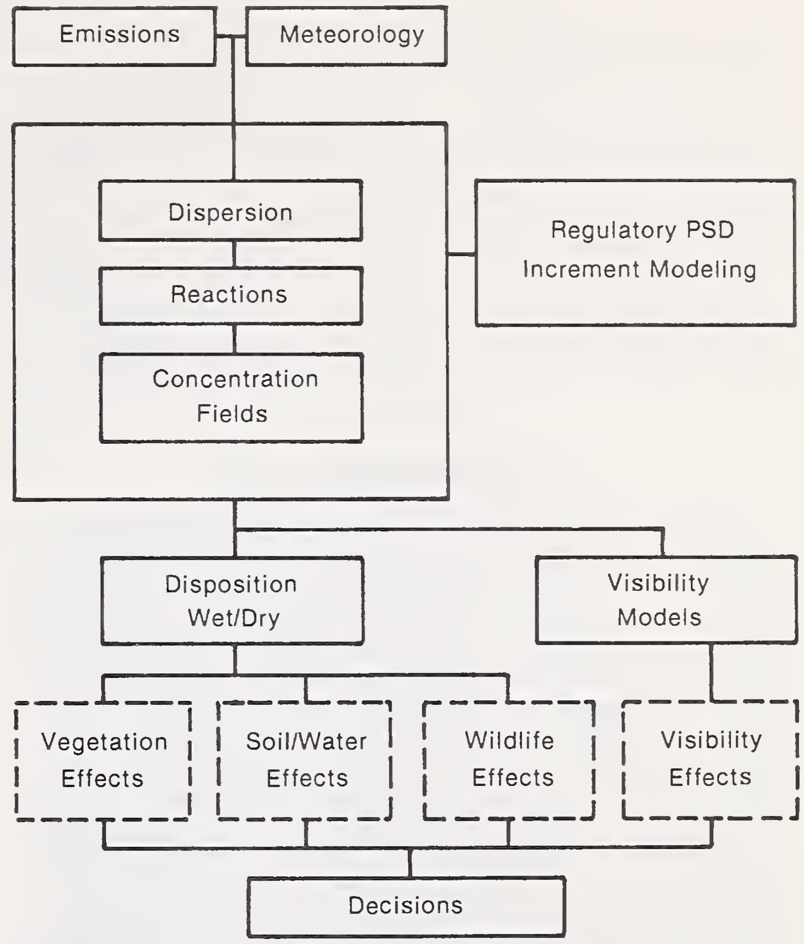

Figure 3.--Air quality modeling required to support decisions based upon AQRV determinations. (For more detail, see Group Report 5.)

protection. While the specifics apply to the Flat Tops Wilderness, the procedure is suggested as a model that can be applied to all Class I areas to accomplish the following results:

- Public identification of the scope and the nature of AQRV's on a Class I area specific basis.
- Direct interaction between specialists and local federal land managers.
- Early information relating to the nature of potential inputs and a plan to address further evaluation.

GROUP REPORTS

1. VISIBILITY

W. Malm, D. Haddow, W. Herrett,
D. Latimer, E. Martin, R. Miller

INTRODUCTION

The Clean Air Act singled out visibility from air quality related values (AQRV's) and, in fact, directed the establishment of a regulatory program to provide for the achievement of, as a national goal, "The prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution" (Clean Air Act, 169A(a)(1)). Subsequently, the USDA Forest Service conducted a workshop aimed at defining methodologies to quantify the value of visibility (Fox et al. 1978). The Environmental Protection Agency (1979) reported to Congress that "nearly all managers of Class I areas indicated the need to prevent existing visibility conditions from deteriorating as a result of new source impacts." Their data were taken from surveys conducted by the U.S. Departments of Agriculture and Interior. The importance of visibility to Colorado wilderness users has been indicated by a number of studies. In a recent study of the cost effectiveness of wilderness, Colorado residents stated that "viewing the scenery" was first in importance among a comprehensive list of 20 specific wilderness experiences that respondents were asked to rate from unimportant to extremely important (Walsh et al. 1982). These same respondents ranked "protecting air quality" second among 13 specific reasons for valuing wilderness.

In a continuing sequence of research studies, B. L. Driver and his colleagues have attempted to quantify the significance of various wilderness experiences to recreationists. Users of the Indian Peaks area selected "clean fresh air" as first out of 73 physical attributes that contributed to their satisfaction.[3] A recent study[4] attempted to identify (1) physical resource attributes of wilderness "that users perceived either added to or detracted from the level of satisfaction obtained," and (2) "the psychological outcomes (immediate benefits) that users perceived either added to or detracted from the level of satisfaction obtained" for three Colorado wilderness areas, Weiminoche, Eagles Nest, and Rawah. The results support the concept that clean air is a major attribute of wilderness and that it contributes significantly to visitors' enjoyment. Physical resource attributes identified by over 250 users of these three wilderness areas were ranked, according to a numerical scale, from strongly adding to satisfaction, to most strongly detracting from satisfaction. The relative ranking of eight general groupings of these physical resource attributes was the same for all the areas, namely:

1. Water related (e.g., cascading streams, mountain springs, waterfalls).
2. Vegetation (e.g., alpine meadows, wildflowers, forests).
3. Attractive topography (e.g., steep hillsides, rock peaks, rugged terrain).
4. Large wildlife (e.g., elk, bighorn sheep).
5. Small wildlife (e.g., beaver, eagles).
6. Fish related (e.g., good fishing streams, trout).
7. Nuisance topography (e.g., rock slides, boulder fields).
8. Bad weather (e.g., hail and sleet, wind, unpredictable).

Attractive topography appears to be related to good visibility, although the connection has not been scientifically established. Psychological outcome domains were ranked on a similiar basis from most strongly adding to satisfaction, to most strongly detracting from satisfaction by wilderness users. Among the general groupings, "relationships with nature" was first, and "escaping physical pressure" was second, in all three wilderness areas. Within the first category, "enjoying the scenery" and "enjoying the sights and sounds of nature" ranked either one or two among <u>all</u> the psychological benefits perceived by users. The numerical rankings, in fact, showed these as dramatically higher than all the others. Driver and colleagues (1979) and Loomis and Green (1979)

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[3]Final Report: Identifying resource attributes providing opportunities for dispersed recreation. By P. J. Brown, G. E. Haas, and M. J. Manfredo, submitted to R. S. Driscoll, Rocky Mountain Forest and Range xperiment Station, Fort Collins, Colo., November 1977.

[4]Final Report: Relationships between resource attributes and psychological outcomes perceived by wilderness recreationists. An unpublished report by P. J. Brown and G. E. Haas, submitted to B. L. Driver, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., March 1980.

are continuing to attempt quantification of the wilderness user experience, in particular with regard to visibility. Nevertheless, it seems safe to tentatively conclude that the ability to enjoy western Colorado scenery through pure clean air is one, if not the single most, important wilderness attribute as perceived by wilderness users.

It is also important to note that, based upon opinions of users and managers alike, visibility in the Flat Tops Wilderness is presently considered to be unimpaired.

The Forest Service should consider an adverse impact on visibility to be visibility impairment resulting from sources subject to PSD permitting, which interferes with the management, protection, preservation, or enjoyment of the visitor's visual experience of the Flat Tops. This determination will be made on a case-by-case basis, taking into account the geographic extent, intensity, duration, frequency, and time of visibility impairments, and how these factors correlate with (1) times of visitor use and (2) the frequency and timing of natural conditions that reduce visibility. There are four questions that must be answered before it is possible to identify an adverse visibility impact, namely:

1. What is the current visibility environment?
2. What amount of visibility impairment is likely to be caused by proposed sources?
3. To what extent will this impairment be perceptible to users of the area?
4. To what extent will this visibility impairment affect the management and use of the area?

The first of these requires an identification of the visual attributes of the Flat Tops and monitoring of current conditions. The second requires extensive modeling of specific proposed sources and their impact on visibility of the area (Lattimer and Ireson 1980). The third may require site-specific studies of the perception of visibility by visitors to the Flat Tops (Malm et al. 1981). And the fourth requires a decision (Fox and Rosenthal 1981) based upon the evidence accumulated in the first three, as well as other factors. The major point is, simply, that existence of a plume or haze perceptible by wilderness visitors does not necessarily mean that an adverse impact on the visual experience of visitors will result. When the technical work of determining the likelihood of a perceptible plume is completed, only half the job is done. The next task of determining the significance of this plume to users of the area must be accomplished by the federal land managers.

THE FLAT TOPS VISUAL RESOURCE ATTRIBUTES

To identify the Flat Tops visual attributes that should be considered for protection, it is necessary to identify key viewpoints and views currently enjoyed by wilderness users. It should be possible to identify a few key views that would adequately protect the important visual attributes of the entire wilderness area. Visitor use of each key viewpoint should be inventoried by time of year, time of day, and frequency (number of users). Big Marvine Peak has been initially identified as the key viewpoint most representative of the visual resources in the Flat Tops. Views from Big Marvine Peak include the Uintas, La Sal Mountains, Mt. Zirkel, Gore Range, and the Elk Mountains.

MONITORING OF VISIBILITY

To determine potential and actual visibility degradation from sources subject to PSD permitting, it is necessary to develop a visibility monitoring program in the Flat Tops. The site suggested for the visibility monitoring station is Big Marvine Peak. The visibility parameters that should be monitored include visual range and contrast reduction of key view elements. The monitoring package should include five automated camera systems recording pictures of selected targets within the Uintas, La Sals, Mt. Zirkel, Gore Range, and Elk Mountains.

In addition to the camera system, two telephotometers should be directed toward the La Sal and Uinta Mountains. The telephotometers will yield contrast data that will establish existing visibility levels as well as an approximate pollutant concentration along the two sight paths. Data from these instruments can be used to "calibrate" concurrently taken photographs so that the photos can be used to extract quantitative visibility data over a wide range of views. The cameras and telephotometers can be operated with 12-volt batteries recharged by solar panels. Monitoring stations within the wilderness will have to be operated without commercial power.

Included in the visibility monitoring package should be a remotely operated weather station. Without such data, it is impossible to determine the cause of any visibility impairment. Meteorological parameters needed are wind speed and direction, humidity, and temperature. These can be monitored easily with a remote automated weather station (RAWS) of the type used extensively for fire weather observations by the USDA Forest Service and other agencies.

It is also necessary to establish existing concentrations of the following gaseous and particulate pollutants that reduce visibility, and then to monitor them:

1. Particulates
   a. Size distribution
   b. Elemental analysis (e.g., sulfates, nitrates)
2. Gaseous Concentrations
   a. Sulfur dioxide (SO_2)
   b. Nitrogen oxides (NO_x)
   c. Hydrocarbons
      (1) Aldehydes
      (2) Olefins
   d. Ozone (O_3).

The electrical power and access requirements of this type of air pollution monitoring program make it nearly impossible to place the equipment within the wilderness area. The suggested location of this monitoring package is Burro Mountain, which lies near the west boundary of the Flat Tops. This can be accomplished by extending existing power lines approximately 1.6 km.

All monitoring should be carried out consistent with EPA's "Interim Guidance for Visibility Monitoring" (1980).

ADDITIONAL STUDIES REQUIRED

Studies of users' perceptions and experiences, specific to the Flat Tops, have been initiated.[5] A study involving 222 Flat Tops visitors showed that "relationships with nature" proved to be the major psychological outcome contributing to users' enjoyment, while meadows and forests proved to be the major physical attributes contributing to this enjoyment. Users were not polled directly regarding visibility or its degradation. In order to tie more specifically into the significance of visibility, additional user surveys should be designed and conducted, building upon the knowledge already gained but focused directly on visual experiences.

Since the visibility regulations specifically refer to visibility impairments with regard to the visitors' use of an area, a short study should be undertaken to quantify such factors of visitor use as times, locations, and numbers of visitors, if such information is not already available. Perception, specific to the Flat Tops Wilderness, also needs to be defined for various levels of visibility impairment. This latter task can probably be best accomplished by using photographs of Flat Tops vistas with simulations of the visual effects of various levels of pollution. All of this research is aimed at quantifying the visual experiences and impacts of degraded visibility in the Flat Tops Wilderness.

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[5]Psychological outcomes and physical resource attributes of the environment--the Flat Tops case. An unpublished report by P. J. Brown and G. E. Haas, submitted to B. L. Driver, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., June 1978.

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2. SOIL/WATER EFFECTS

J. Turk, S. Fifer, and W. Marlatt

BACKGROUND AND EXISTING DATA

Geology

The Flat Tops Wilderness is located on the White River Plateau, a relatively flat, high-lying area that has been moderately dissected by stream erosion and glacial action. The exceptionally flat appearance is supported largely by tertiary age basalt flows, which are relatively resistant to erosion. Fluvial and glacial dissection have in places exposed underlying sedimentary formations of Mesozoic and Paleozonic age. Where this dissection has cut through the basalt into the softer sedimentary rocks below, erosion has progressed at a more rapid rate, creating the steep canyons characteristic of this area.

The watersheds in the north and eastern sections of the wilderness have a larger proportion of "soft" sedimentary formations (Brown's Park, Maroon, Evaporites) throughout their sides and bottoms than those in the west and, consequently, are more readily erodible. The western watersheds, comprised mainly of the South Fork White River and its tributaries, have more limestone and basalt and are relatively more erosion-resistant.

Climate

Climatic conditions are typical of middle-latitude, high-elevation areas, characterized by warm summers and cold winters. Temperatures have a broad seasonal and daily variation because of a wide range of elevations and exposure. The mean annual temperature at Meeker (elevation 1,935 m) is 6.6° C, with extremes of -41° to 39.4° C. Forty kilometers east of Meeker the mean annual temperature at the Marvine Ranch (elevation 2,380 m) drops to 2.7° C.

Annual precipitation varies from 31.7 cm at Meeker to over 88.9 cm in the high-elevation areas of the Flat Tops Wilderness. Seasonal distribution of precipitation at the lower elevations is fairly uniform during the year. About 40% of the precipitation comes as snow during the December-April period. At higher elevations, snowfall accounts for approximately 70% of the annual precipitation. This accumulation of winter snow is the principal source of streamflow. Summer rainfall generally takes the form of showers that contribute little to overall water supplies. The summer precipitation is highly variable, coming from large, moist air masses and short-duration, high-intensity thunderstorms.

The combination of low temperature and great topographic relief makes the water resources of this area especially susceptible to atmospheric emissions. Prevailing wind components from the southwest and north will move air masses from oil shale development and coal-fired power plants in the Yampa Valley across the Flat Tops Wilderness area. The orographic effect of the Flat Tops is the first barrier to these air masses and should result in deposition of emissions before extensive dispersion has occurred. Additionally, the low temperatures promote the accumulation of a snowpack that is released in a short period of time, which minimizes reactions with soil and bedrock.

Streams

The Flat Tops Wilderness serves as an important water supply for the entire White River Basin. Each year more than 51,000 m^3 of water is generated from the wilderness area. The water comes principally from the melting snowpacks on the high mountains, augmented to a small degree by summer precipitation. Streamflow is highly dependent on the annual spring runoff, when temperatures are high enough to melt the snowpack. The streams reach a peak flow during June, when as much as 40% of the total annual water yield is derived. Over 75% of the water is derived during May through August. Streamflows are at a minimum during November through March, when most of the water is derived from ground water sources. Figure 4 shows the runoff distribution of the South Fork of White River, which is typical of streamflows within this wilderness area.

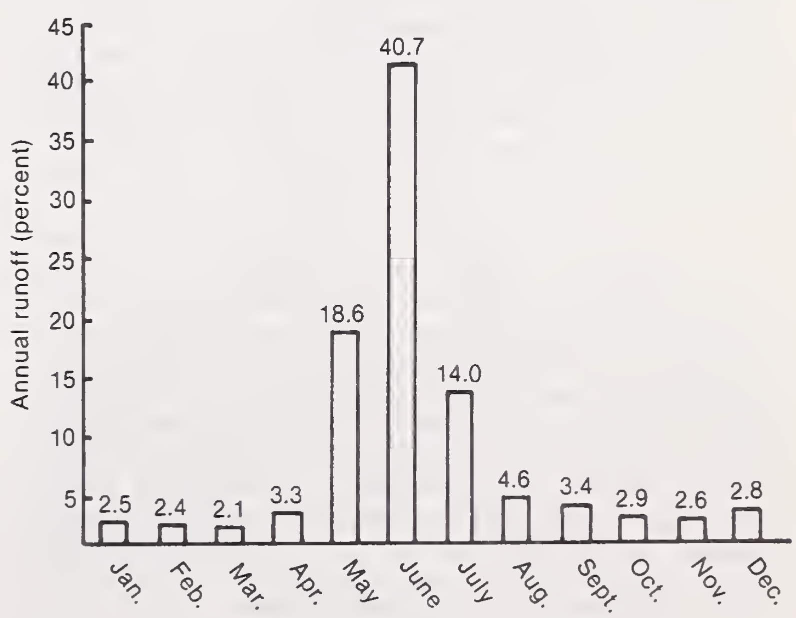

Figure 4.--Mean annual runoff distribution White River near Budges Resort, Colorado.

Water yield per unit area increases with elevation. In the alpine zone, where the ground cover is essentially rock, the annual runoff is extremely high, averaging 88.9 cm. At lower elevations, between 2,700 and 3,000 m, water yields drop to 45.7 cm. This relationship occurs primarily because of increased precipitation at higher elevations and a decrease in water consumed by vegetation.

Water Quality

Water quality information from within the Flat Tops Wilderness is available from a number of sources. Studies have been, or are currently being conducted, by the USDA Forest Service, U.S. Geological Survey, and the U.S. Bureau of Reclamation. The longest, continuous, water quality records from this area are maintained by the U.S. Bureau of Reclamation. Beginning in 1962, total dissolved solids (tds) and streamflows, recorded in cubic feet per second (cfs), were measured on the North and South Forks of the White River near the town of Buford. The total dissolved solids measurements reflect the chemical quality of the stream. They indicate the presence of carbonates, bicarbonates, chlorides, sulfates, or phosphates. The U.S. Geological Survey maintains seven streamflow measuring sites in Colorado near the Flat Tops Wilderness: Marvine Creek near Buford, North Fork White River at Buford, South Fork White River at Buford, South Fork White River at Budges Resort, Wagonwheel Creek at Budges Resort, South Fork White River near Budges Resort, and the South Fork White River near Buford. Currently, the U.S. Geological Survey is monitoring specific conductance and temperature at the seven discharge monitoring sites. Specific conductance, like total dissolved solids, is an indicator of stream salinity.

The USDA Forest Service maintains 11 sampling stations in, or adjacent to, the Flat Tops Wilderness; data collection was initiated in 1978. The parameters monitored include suspended sediment, turbidity, temperature, conductivity, dissolved oxygen, pH, alkalinity, total hardness, calcium hardness, and stream discharge. The monitoring objectives of these stations are to define present water quality conditions and to provide information useful in the interpretation of the effects of future management activities.

In general, the water quality of the streams and tributaries within the wilderness is of very good quality. The measured parameters are within the standards established by the State of Colorado for recreation, cold-water fisheries, and irrigation uses. Dissolved oxygen and pH remained relatively constant through the summer, while temperature, suspended sediment, alkalinity, hardness, and specific conductivity showed seasonal trends and varied with streamflows. A summary of water quality data collected at the USDA Forest Service sampling sites is available from the White River National Forest.

The streams were well oxygenated throughout the summer. Dissolved oxygen concentrations varied between 6 and 11 mg/1. The concentrations remained high at lower streamflows because of cold-stream temperatures and good aeration from the turbulent flows of these streams.

Variations in alkalinity, hardness, and specific conductivity measurements were caused by the "diluting effect" of the early-season spring runoff. During the spring high-flow period, most of the runoff comes directly from high-quality snowmelt, which is very low in carbonates, bicarbonates, and dissolved solid concentrations. Consequently, concentrations of these in receiving streams are diluted, resulting in lower alkalinity and conductivity measurements. Later in the season, when streams are less dependent on the snowmelt runoff, the concentration of dissolved solids increases and the measurements are higher.

Consistently higher conductivity measurements were recorded in the Sweetwater and Marvine Creek watersheds (290-300 µmhos/cm). Lower values were observed in the South Fork White River and its tributaries (150-240 µmhos/cm). This difference, although slight, is attributed to the geologic difference between the watersheds. The Marvine and Sweetwater Creek watersheds have a significant number of "soft" sedimentary formations (Browns Park, Maroon, Evaporites). This material is more readily eroded and contains more water-soluble minerals than the limestone and basalt found throughout the South Fork White River.

The suspended sediment and turbidity measurements were highest during spring runoff, but they remained relatively low throughout the sampling period. The highest measurements were found in the Marvine, Sweetwater, and Ripple Creek watersheds. As with conductivity, the higher values are attributed to the presence of "soft" sedimentary formations in the watersheds. The lower values observed in the South Fork White River result from the predominance of erosion-resistant rock (basalt, limestone) in the watershed.

The alkalinity values indicate the streams have a relatively good buffering capacity. This means the pH of the stream systems will not be changed greatly by the addition of moderate quantities of acid (such as might be caused by oil shale development). The alkalinity is primarily attributable to the presence in the water of carbonates (CO_3) and bicarbonates (HCO_3), deriving from the atmosphere (CO_2) and the limestone ($CaCO_3$) and other sedimentary rocks in the watershed.

Precipitation

Snow surveys have been conducted by the USDA Soil Conservation Service in the headwaters of the North and South Fork White Rivers since 1936. Total snow depth and snowpack water content are measured each month, February through May. These measurements help forecast available water supplies for the coming year. Snow course records for 1936-1972 are available from the Soil Conservation Service.

Daily precipitation data are available from stations located at the Marvine Ranch, Meeker, Maybell, and Douglas Pass. Precipitation quality data were collected at the Maybell and Douglas Pass sites starting in 1980; data measured include major ions, major nutrients, pH, and specific conductance. The length of record is insufficient for definitive characterization of precipitation quality. However, values of specific conductance of about 4 µmho/cm with pH values less than 6 indicate that minor additions of dissolved solids could markedly change the chemical character of the precipitation.

Lakes

A reconnaissance of 15 lakes was made by the U.S. Geological Survey in July-September 1980. Data from this study include profiles of temperature, specific conductance, major ions, nitrogen and phosphorus speciation, heavy metals, alkalinity titration curves, and lake volume.

The data indicate a wide range of chemical and biological characteristics among the lakes studied. Alkalinity, a measure of the buffering capacity towards acidification, ranges from about 5 to 70 mg of $CaCO_3$ per liter. Lakes with the smaller alkalinity values are located above the canyon rims on the basalt caprock. The more highly buffered lakes are in the stream valleys, and they probably receive a greater component of ground water from glacial deposits and fractured basalt than do those on the caprock itself. The lowest levels of alkalinity reflect dilution of added acid rather than neutralization by reaction with bicarbonate. The low levels of alkalinity in lakes such as Upper Island, Shingle, and Surprise make them susceptible to decreased pH from even small amounts of added acid.

Dissolved oxygen, necessary to support all higher forms of life, was found to vary from supersaturation to complete absence below the thermocline in some lakes. The addition of critical nutrients, which would increase productivity, could accelerate oxygen depletion during the period of snow cover.

Soils

Fairly detailed soil surveys have been completed for much of the western and northern portions of the Flat Tops Wilderness area (all of Rio Blanco County) (Order 3 level). Three soil mapping units are identified:

1. Dark-colored soils on the cold, forested mountain slopes.--Most of these soils are at elevations between 2,400 and 2,850 m. Parent rocks are principally sandstone, shale, quartzite, and basalt. Underlying parent materials are permeable and often calcareous.

   These soils have dark-colored, moderately thick, granular A_1 horizons and light-colored A_2 horizons which tongue into blocky, clayey, low-permeability subsoils. Bedrock is usually more than 1.2 m under the surface. Surface soils are loam to sandy loam and are generally high in organic matter. Near neutral pH exists. Little erosion is noted.

2. Light-colored soils on the cold, forested mountain slopes.--These soils are found at elevations of 2,400 to 3,300 m (particularly 2,700 to 3,000 m) on slopes that are generally steeper than those of the dark soils. Parent materials are mostly reworked granite, sandstone, shale, and basalt. Glacial, colluvial, and alluvial deposits are common along lower slopes and drainage ways.

   These soils are generally loamy, low in organic material, and have very thin or no A_1 horizons. The A_2 horizons are light-colored, moderately thick, and slightly acidic. Subsoils are generally quite deep and permeable and range in texture from sandy loam to clay.

3. Shallow and deep, dark-colored soils of the alpine region.--These soils are found above timberline at elevations between 3,300 and 3,600 m. Average annual temperature is less than 0° C; however, daily and seasonal surface temperature ranges in the microlayer are often extreme. Parent materials are generally basalt and granite, with lesser areas of shale and sandstone. Bedrock, often near the surface, is usually no deeper than 25-75 cm.

   Soils in topographic depressions are often poorly drained, are high in organic material, and peaty. Well-drained areas are dark colored, high in organic material, and generally acidic. Textures range from gravel, stoney, to sandy loam. Subsoils are mostly gravelly or stoney sandy loams, readily permeable and mildly acidic. Productivity is low because of the low soil temperature.

   The baseline soil chemistry is not available for the soil types in the Flat Tops Wilderness area. As a result, it is difficult to identify changes that could occur as a result of materials brought in via atmospheric pathways. Acid-producing materials and toxic substances in significant concentrations will probably be more readily identified in other components of the ecosystem (e.g., lakes and vegetation).

RECOMMENDATIONS

Short Term

Judging from the available data, the most sensitive indicators of effects of atmospheric emissions on the hydrologic system are precipitation quality and the quality of poorly buffered lakes, such as Surprise, Upper Island, and Shingle. Streams, well-buffered lakes, and soils would probably not show observable effects of atmospheric emissions until much later than the most sensitive indicators. In response to PSD applications, the available precipitation and lake data, in combination with proponent-supplied estimates of deposition rates of phosphorus (P),

nitrogen (N), sulfur (S), and total acidity, will allow estimation of the effects on the precipitation, especially the snowpack, and the lake systems. In the absence of estimated deposition rates, it should be assumed that some lakes with present low pH values could show some lowering of pH and related fisheries impairment.

Long Term

Although available data are sufficient to indicate that even minor additions of pollutants will produce undesirable effects on the most sensitive indicators, quantitative evaluation of cumulative effects and even of future PSD applications will require substantial new data and data interpretation capability. Primary needs are for greater sampling density, knowledge of the present variability, identification and quantification of critical watershed processes, and models capable of relating cumulative emissions to deposition rates. Therefore, a major monitoring program, as described below, is warranted.

1. Streams.--The USDA Forest Service plans to continue monitoring stream water quality in and adjacent to the wilderness boundary to fulfill the direction outlined in the Flat Tops Wilderness Management Plan and Forest Watershed Management goals. Based upon analysis of the Forest Service's water quality data and specific monitoring needs identified in this workshop, we recommend the monitoring plan be modified by reducing the existing 11 monitoring stations to 6 and adding 2 to 3 new sites in high elevation headwater areas.

A CLUSTER analysis of Forest Service water quality data from 1978 to 1980 indicates there is not a significant difference between the water quality measured at several of the 11 stream monitoring stations. This is attributed primarily to homogeneous geologic conditions in these watersheds. Based upon this analysis, it would be more efficient to reduce the existing 11 sites to 6. Although the data suggests these streams are alkaline and, as such, not good indicators of acid pollution, they are needed to provide valuable information on long-term cumulative impacts associated with offsite development. In addition, because the six monitoring sites are located in the lower portion of major drainages and at similar elevations, we recommend adding two to three stations in high-elevation headwater areas. These stream systems may not be as alkaline as the lower sites and, consequently, are expected to be more sensitive to impacts of atmospheric deposition. These new sites can be identified after a synoptic reconnaissance of the high-elevation streams.

2. Precipitation.--The existing data base is hampered by the small number of stations, short length of record, and lack of data for the high-altitude areas where the most sensitive lakes are located. Data on precipitation quality are especially inadequate. Long-term wet/dry precipitation collectors with associated meteorological monitoring equipment, as well as a network of quantity/quality snow courses, should be established. It is especially important to measure quality of the snowpack on the mesa above 3,150 m.

Related to the precipitation data needs is a need for an applicable atmospheric transport/deposition model. This model should be capable of handling both regional and local emission sources and of calculating deposition rates at altitudes in excess of 3,150 m.

3. Lakes.--After reconnaissance-level investigation is complete, the lakes should be grouped into categories representing various levels of alkalinity and productivity. Representative lakes of these groups should be selected for long-term monitoring and for investigation of critical system processes. Monitoring should include both biological and chemical components of the system. Algal, invertebrate, and fish population structures, and primary productivity would be suitable for the biological component. Chemical components should include diurnal characteristics of pH and dissolved oxygen as well as major ion, major nutrient, and selected trace constituent analyses. Sampling frequency should be sufficient to identify the normal seasonal variation in many of these characteristics.

Critical system processes also include both biological and chemical components. Biological processes should include bioassay of primary producer and other trophic-level response to nutrients and toxic constituents expected from atmospheric emissions (e.g., boron (B), molybdenum (Mo), arsenic (As), phosphorus (P), nitrogen (N), and fluorine (F)). Reproductive success and relationships between predators and prey should also be evaluated.

Chemical processes should include evaluation of budgets for indicator chemical components, including determination of sites of weathering and probable response to pH changes in precipitation. Also important would be the mechanisms of constituent recycling within the lakes themselves, particularly for nutrient species.

4. Soils.--In addition to baseline soil chemistry--cation-exchange balance, nutrient levels, trace elements, and microbiology--a statistically reproducible sampling methodology needs to be developed. It may well be that certain microfauna in the soils at high elevation are sensitive indicators of changes in soil trace elements. These have not been identified, nor have threshold levels been determined.

3. FISH AND WILDLIFE

J. Newman, K. Schreiber, L. Jensen,
B. Rios, and J. Sarazin

INTRODUCTION

Present and future development of oil shale in the vicinity of the Flat Tops will affect existing and future air quality of the area and, possibly, the fish and wildlife resources of the wilderness area. Objectives of this report are to:

1. Identify air quality related values (AQRV's) for fish and wildlife in the Flat Tops and sensitive receptors that may exist for each value.

2. Determine what information regarding fish and wildlife AQRV's is either presently available or needs to be collected in order to review and make recommendations for oil shale PSD permits.

3. Determine what short-term and long-term monitoring of fish and wildlife may be necessary on the Flat Tops to measure possible effects on fish and wildlife AQRV's from oil shale development.

EXISTING RESOURCES

The major species of fish in the Flat Tops Wilderness include the native cutthroat, rainbow, and brook trout. Many of these are stocked by the Colorado Division of Wildlife because there is heavy fishing pressure on most fisheries in the wilderness area.

Large mammals found in the Flat Tops Wilderness include American elk, mule deer, black bear, coyote, and mountain lion. Elk and deer are very important to the area recreationally, economically, and biologically. The White River elk herd is one of the largest herds in Colorado, with 4,000-5,000 animals present in the area during the summer. This herd has, in the past, been known to be one of the best herds for trophy hunting, and it is located in one of the finest hunting areas in the state. Portions of the largest deer herd in Colorado summer on the Flat Tops. The abundance of black bear results in many conflicts with domestic sheep during the summer. Coyotes are also very abundant in the area and also cause conflicts with domestic sheep bands. There are no grizzly bears or wolves present. The Colorado Division of Wildlife is planning to reintroduce bighorn sheep into the Sheep Mountain vicinity on the eastern side of the wilderness area.

Small mammals commonly found in the area include snowshoe hares, ground squirrels, pine squirrels, chipmunks, pocket gophers, pikas, porcupines, and marmots. Dominant furbearers include the red fox, bobcat, coyote, weasel, and beaver.

A wide variety of bird life is present, with cavity nesters such as woodpeckers, sapsuckers, and flickers being abundant. Raptors such as red-tailed hawks, Swainson's hawks, golden eagles, and great horned owls are common. Blue grouse, ptarmigans, juncos, finches, crows, ravens, jays, and Clark's nutcrackers are also found in abundance. Waterfowl such as mallards and teals use the many small lakes in the wilderness.

DEFINITIONS AND ASSUMPTIONS

Several assumptions and definitions served as the basis for developing the fish and wildlife AQRV's. In identifying AQRV's and the possible significance of air pollution upon them, the legal concept of wilderness was kept in mind. The AQRV's suggested are values that, if changed, might have an adverse effect on the Flat Tops Wilderness. The AQRV's defined by this group reflect a hierarchal progression starting with (1) values of societal significance, progressing down through (2) ecological or wilderness management values, and ending with (3) values reflecting specific fish and wildlife species of special recognizable value otherwise not covered.

There is a lack of species-specific information on dose/response relationships for many of these fish and wildlife AQRV's. We have, therefore, attempted to identify those that potentially could be affected by air pollutants. This identification is based on our present understanding of the reported effects to specific fish and wildlife groups or analogous groups such as domestic animals. It is assumed that three pathways of contamination of fish and wildlife by air emissions will exist: inhalation, ingestion, and absorption. In terms of priority, the second level of AQRV's may be considered of highest priority to the Forest Service because these AQRV's relate most directly to the Flat Tops Wilderness management plan.

For the purpose of this group report, the term "adverse effects" is based on measuring a change from the natural state, including physiological, behavioral, and/or ecological change.

Categories of AQRV's

Suggested AQRV's related to fish and wildlife of the Flat Tops Wilderness area, along with suggested sensitive receptors, are grouped into three hierarchal levels or categories:

1. AQRV's of general societal significance: Values for fish and wildlife, based on human use, that may be affected by changes in air quality.
    a. Big game hunting--elk, deer.
    b. Sport fishing--cutthroat trout.
    c. Wildlife esthetics (photography, bird watching)--elk, pika, ptarmigan, others.
    d. Trapping--beaver, marten, weasel.
2. Wilderness management AQRV's: Ecological indicators used for monitoring wilderness value (highest priority).
    a. Indicators of ecotypes.
        (1) Streams, lakes.
        (2) Spruce-fir.
        (3) Aspen.
        (4) Riparian.
        (5) Alpine-meadows.
        (6) Grassland.
    b. Indicators of important functional wildlife groups based on established relationships between the groups and their habitat requirements.
    c. Indicators of wilderness integrity.
        (1) Wildlife species richness/diversity.
        (2) Wildlife health/vigor (e.g., as detected through tissue/organ analysis).
        (3) Habitat quality.
3. Special species AQRV's: Fish or wildlife species, other than those above, that merit special concern because of special legislation, scientific value, or sensitivity to air quality degradation.
    a. Endangered/threatened species--federal and state (e.g., Colorado greenback cutthroat trout).
    b. "Type" species--gene pool preservation, endemic species/subspecies, voucher specimens.
    c. Species at the edge of their range or in restricted habitats (e.g., habitat requirements are barely met), such that any additional stress (e.g., air quality degradation) may produce detectable change in their population and/or their range.
    d. Other species especially sensitive to air pollution, (e.g., aquatic or terrestrial invertebrates).

Interception Points

Fish and wildlife encounter or are exposed to air pollutants directly from the air; indirectly through vegetation, soils, or other land-based routes; and indirectly through the water. The exposure medium on the point of interception should be identified for each specific fish and wildlife AQRV.

Air

The airshed is the first point of interception for fish and wildlife species of airborne pollutants. Receptors at this level might include bird species or flying insects which would inhale pollutants. Lung tissue in selected species would be the sensitive receptor.

Land

The next level of interception, the land, is more complicated because it reflects possible modification of the original pollutant by interaction with vegetation, soils, etc. Terrestrial species, which might be affected directly by inhalation, may also be affected indirectly through ingestion of contaminated vegetation or water. Primary consumers could be the first-level receptors.

Water

Water systems represent a third, and perhaps most complicated, level of interception because the air pollutant may have interacted with vegetation and soil before settling in the aquatic systems; thus, its effect may be greater than or less than in its original form (i.e., biomagnified or converted into more toxic forms).

Selection of Sensitive Receptors

Criteria for selecting sensitive receptors (indicator species) should include the following:

A. Ease of monitoring as determined by
    1. abundance
    2. census techniques
    3. costs.

B. Certainty of diagnostic effects of receptors to air emissions emphasizing
    1. species with known physiology, life history, etc.
    2. species with known sensitivities or sensitive life stages.

C. Ecologically important species including
    1. stenotrophic sensitive species

Table 3.--A preliminary attempt at identification of sensitive receptors for fish and wildlife AQRV's

Categories of AQRV's	Interception points		
	Air	Land	Water
Societal significance			
Big game hunting	None	Elk - aspen quality Deer-browse quality	None
Sportfishing			Cutthroat trout - alkalinity changes
Wildlife esthetics	White-crowned sparrows - lungs	Elk - aspen quality Ptarmigen - willows Pika - food	None
Trapping	None	Beaver - aspen quality and quantity	Beaver - water quality - aquatic vegetation

2. species with critical/sensitive life stages
3. species with unique habitat characteristics
4. species at extension of their range or living naturally in suboptimal habitats.

A Matrix Approach

It is suggested that a matrix format be developed in which the rows represent categories of AQRV's broken down to specific levels within the three general categories (1) societal significance, (2) wilderness management, and (3) special species, considerations mentioned earlier. Three columns representing the interception points--air, land, and water--would be used to fill out the matrix. Data to be placed in the matrix would be specific species of fish and wildlife as critical biological, chemical, or physical elements which can serve as an indicator or most sensitive species for that AQRV category at that interception point.

For example, under societal significance, the breakdown shown in table 3 might occur.

It is somewhat more complicated to complete the remainder of this type of matrix. The three subcategories under wilderness management break down into a large number of individual ecotypes, of habitat/functional groupings, and of wilderness integrity measures. Indicator species/elements must be determined for each interception point. For example, a wilderness integrity measure selected might be wildlife health and vigor. The air interception point might consider elements such as nesting success and clutch size of raptors and insect-avaricious birds. The land interception point might consider elements such as sex rations, calf crop, and teeth of harvested elk and deer. The water interception point might consider productivity and growth of salmonid fishes and the like.

RECOMMENDATIONS AND NEEDS

Specific Information Needs for the Flat Tops Wilderness

Relatively good information exists on the Blanco and Rifle Districts regarding the fish and wildlife resources of the Flat Tops and their ecological interactions. This information needs to be compiled and synthesized for refining and/or identifying sensitive receptors for some of the AQRV's. Inventories exist on most vertebrate species, with the possible exception of reptiles, amphibians, nonsalmonid fish, and on key terrestrial and aquatic invertebrates. General habitat and food relationship information exists for most fish and wildlife groups. This information needs to be synthesized and significant data gaps identified. A preliminary list of information needs for the Flat Tops would include:

1. Identification of wilderness management AQRV's as related to wildlife groups:
    a. Indicator species of each group.
    b. Groups classified by habitat considerations.
2. Identification of endangered and threatened species and of their actual or potential locations.

3. Identification of species' extension of their ranges as restricted by habitat.

4. Identification of fish and wildlife species sensitive to air pollutants.

5. Identification of ecological attributes of wilderness area as they relate to:

   a. Identification of wildlife species, numbers, and kind--vertebrate, invertebrate, insects, etc.

   b. Vigor and health of wildlife.

   c. Quality of fish and wildlife habitat.

6. Exposure routes for air contaminants including inhalation, ingestion, absorption.

7. Effects of contaminants, including both short- and long-term effects; information on seasonal exposure potential (i.e., snow melt pH changes in aquatic systems) is needed.

8. Seasonal sensitivity of specific AQRV's. Depending upon their age or life cycle, both fish and wildlife have differential sensitivity to toxic conditions. Information on these sensitive periods for each animal group needs to be developed.

9. Baseline levels of trace elements in AQRV's receptors in wilderness area.

10. Comprehensive inventories and mapping of wilderness area by ecological resources and by AQRV's.

11. Regional plan addressing location of facilities to avoid identified sensitive wildlife areas.

12. Coordination with U.S. Fish and Wildlife Service, USDA Forest Service, U.S. National Park Service, U.S. Bureau of Land Management, U.S. Geological Survey, and Colorado Division of Wildlife on common methods for air quality assessments.

13. Need for vegetation information on plant species that accumulate pollutants; and on vegetative species sensitive to pollutants, especially vegetation critical to wildlife habitat.

14. Need for air emission information for specific oil shale developments:

   a. Air isopleths of pollutant concentration, along with descriptive statistical analysis of confidence limits. Used to identify hot spots.

   b. Range of emission levels (high and low values) and frequency of occurrence of these values.

   c. Air quality information at 1-hour averages in addition to 3-hour and 24-hour averages.

   d. Probability of inversions--where they could occur and how long they could last.

   e. Chemical composition of the particulates.

   f. Seasonal information on particulate deposition patterns.

   g. Direction of plume travel and rainfall information.

General Information Needs for Fish and Wildlife AQRV's

The weakest but most critical element for fish and wildlife AQRV evaluation is information on the effects of air emissions. Literature reviews have shown that fish and wildlife are known to be affected. However, the lack of sufficient usable information is not a function of tolerance of fish and wildlife to air emissions, but reflects the lack of observation and monitoring. It is recommended that generalized dose/response relationships for fish and wildlife AQRV-sensitive receptors be developed from existing information. These dose/response relationships could then be applied to establish screening levels for possible effects on representative animal receptor groups. Several scientist-months would be required for this task. Once the fish and wildlife AQRV's have been refined, specific dose/response relationships can be developed. Existing data bases should be reviewed, and an assessment of the potential hazard developed. Some dose/response information is available in the literature, but new testing may be required to supplement information gaps. Emphasis should also be placed on possible seasonal or life stage sensitivities of fish and wildlife to air emissions.

Coordination between the vegetation AQRV's and the fish and wildlife AQRV's is critical, especially in identifying indirect effects for fish and wildlife (i.e., habitat or food impacts). Along with the development of dose/response estimates for fish and wildlife, some standards need to be set for USDA Forest Service evaluation criteria that will be used in assessing whether a potential effect is likely to occur.

Monitoring Needs

For the short term, we recommend utilizing existing monitoring programs within the Flat Tops (i.e., Hunter Check Station, Trappers Lake Facility) to collect baseline information on the health and vigor of fish and wildlife. Information on standard measures of health and vigor should be collected and put in a form usable in a fish and wildlife AQRV assessment. In addition, selected tissues reflecting accumulation sites in mammals should be collected for later analysis to determine background levels of trace elements in selected sensitive receptors. Baseline monitoring should start soon and several years of preoperating data should be developed. Tissue analysis can be deferred until complete monitoring priorities

are established and AQRV's are refined. Once the fish and wildlife AQRV's have been refined, the AQRV resource map developed, and effects information collected and analyzed, a long-term monitoring program should be established to provide information for the key sensitive receptors and the changes during the development of oil shale.

PSD Permitting Procedures

Discussions by the participants led to a 6-step procedure that could be used by federal land managers in evaluating a PSD permit from a fish and wildlife AQRV's perspective.

Step 1a. Identify and develop fish and wildlife AQRV's and AQRV resource map for the area. Would be dependent on the number and location of AQRV's. The resource map could be an overlay format.

Step 1b. Develop specific sensitive-receptor-response information for AQRV's, such as the matrix discussed in the previous section.

Step 2. Obtain and review the PSD application. Ensure that emission type and concentration and deposition information, including isopleth maps for each air pollutant on the appropriate averaging times are available.

Step 3. Based on predicted concentrations identified in Step 2, screen fish and wildlife AQRV's to identify potentially affected values.

Step 4a. Compare location of potentially affected fish and wildlife AQRV's with PSD information on deposition pattern and concentration for each emission type.

Step 4b. Calculate/estimate exposure potential to AQRV's from land- and water-exposure routes.

Step 5. Identify potentially affected AQRV's, resource areas, and potential impacts.

Step 6. Make recommendations for PSD review or seek further information and repeat Steps 3 through 6.

4. VEGETATION

W. Lauenroth, L. Soholt, J. Bennett, D. Summers, and B. Peterson

INTRODUCTION

Deposition of air pollutants in the Flat Tops Wilderness can be expected both on higher elevation plateaus and lower elevation valleys. At the present time, two major pollutants from oil shale technology are considered phytotoxic: ozone (O_3) and sulfur dioxide (SO_2). More information on source emissions and modeling is needed to determine if acidity and metals and other chemicals present a threat.

EXISTING VEGETATION

The vegetation on the Flat Tops Wilderness consists of five major vegetation types: conifers, mixed grasslands, riparian shrubs, aspen groves, and marshes (table 4). Three of these types are patchy in distribution, while conifers and riparian shrubs form discrete stands or linear units. This composite of vegetation forms a continuous, integral system of interacting types which is essential for the multiplicity of uses the wilderness receives (table 4). Thus, while each type has value in itself for one or more uses, a higher value is found in the integral functions of all types (i.e., the whole is greater than the sum of its parts). In this sense, by recognizing that air pollution can affect any vegetation, each vegetation type is considered an air quality related value (AQRV) and may not be isolated or ranked separately from or above any other.

Within plant communities, however, sensitivity of plants to air pollutants at different times of the year depend on the life cycle of the plants, the growth rate, and the life form. Perennial evergreens (conifers) and lichens may be susceptible all year, even though they may be most sensitive during active growth in the spring. The cone-producing season of pines (spring) may also be a sensitive stage of growth, affecting the ability of the species to regenerate. Lichens are especially sensitive to low levels of sulfur dioxide (SO_2), which occur throughout the year. Foliose lichens are more sensitive than crustose types. Deciduous perennial shrubs and trees (e.g., aspen) are most sensitive during the spring flush of new growth, and not sensitive at all after the leaves have fallen off. Both evergreen and deciduous trees are most sensitive to air pollution stress when very young or very mature. Air pollution stress at this stage may delay or speed up flowering, inhibit complete flower formation, decrease the number of leaves and flowers, and hasten mortality. Rosette plants are less sensitive than erectile plants, and grasses are noted for their high sensitivity to SO_2.

Table 4.--Vegetation types of the Flat Tops

Types	Cover	Biomass	Patchiness	Uses
	----(percent)----			
Conifers	60	80	No	Hunting, hiking watershed, animal shelter
Mixed grasslands	27	5	Yes	Grazing, camping, hiking, hunting
Riparian shrubs	1	4	No	Forage, fishing
Aspen	10	10	Yes	Esthetics, forage
Marshes	2	1	Yes	Waterfowl, hunting, fishing
	100	100		

Conifer

Older and overmature stands in the Flat Tops were killed by the spruce beetle epidemic of the 1940's. This opened the canopy and resulted in a lush and diverse understory community of forbs and grasses. The ground cover in the young spruce-fir stands comprises grass and forb species common to the area. Fir and spruce reestablishing on these sites have not had a great deal of influence on the understory community. This will likely change as succession continues and timber stands reestablish and close the canopy again. Fir is the dominant tree species reestablishing in the stands. The overstory is now 25- to 30-year-old trees, ranging in size from 3 to 10 m tall. This type is used mainly for wildlife food and cover.

Grassland

These areas are basically a stable community of grasses and of forbs with patchy stands of willow. Species of Deschampaia, Carex, Poa, Phleum, Trifolium, Mertensia, Potentilla, Agoseris, and Aquilegia predominate, along with Salix planifolia and S. brachycarpa. There are also a variety of lichens and mosses represented within this plant community.

The plant density and composition differs greatly with various slopes, moisture conditions, and soil productivity. Many of the grassland sites over 3,450 m approach an alpine tundra environment where the exposed ridges are typically sod-bound, tufted hairgrass stands, while the small draws contain stands of willow. This type is used primarily for grazing by domestic sheep, summer range for elk, sightseeing, backpacking, camping, and hunting.

Riparian

The riparian shrub types are located in the valley bottoms along the perennial streams. The sites are characterized by willows and plant species associated with wetter sites. Poa spp. and Carex spp. are the dominant grass and grass-like species. Numerous forbs are found. These areas are used primarily for wildlife food and water, fishing, hiking, camping, and domestic sheep grazing.

Aspen

Aspen sites are limited to sites below 2,850 m, generally on south-facing slopes. The understory is typically made up of grass species rather than the aspenweed type. The aspen are generally patchy, open stands. They provide thermal and protective cover and feed for elk and deer. Domestic sheep also show a limited amount of use of the aspen understory. The primary importance of the aspen may be visual because of the variety and color that they produce.

Marshes

Typical marsh sites are limited to portions of the eastern one-half of the upper plateau. These marshlands have evolved over the years from barren potholes that had little vegetation around or in them, to a stage where a variety of carices, Juncus spp., and forbs thrive, at least along the shores. These sites are extremely wet in early summer; but, because of the porous, basaltic soil, parent material, these marshes lose most of the water by late summer. These areas are used for a minor amount of grazing by domestic sheep, elk, and deer.

BIOLOGICAL MONITORING OF VEGETATIVE AQRV's

An indicator species matrix is needed to evaluate adverse impact of the two major air pollutants from oil shale development on vegetation AQRV's (table 5). Several cells in this matrix have been filled, but a field visit by botanists would be needed to complete the matrix. The botanists must have expertise in nonvascular plants, particularly bryophytes, and general familiarity with Rocky Mountain flora. The matrix also identifies preferred responses to be measured on the indicator species. Finally, three miscellaneous indicators of high value that constitute additional AQRV's should be included: (1) rare and endangered species--none known, but knowledge is incomplete, (2) type localities--none known, but knowledge is incomplete, and (3) sphagnum bogs (peat)--acidic wetlands baseline. The botanical survey would also require checking for the presence of rare and endangered species, and any type localities of biotypes. Consultation with a local or regional taxonomic botanist at a herbarium would be the best way to check this. Finally, the presence of sphagnum bogs should be recorded to establish the baseline for acidic wetlands. Sphagnum moss grow best in acidic water.

Concentrations of sulfur and arsenic should be measured in plant samples to establish baseline conditions before oil shale development progresses.

LONG-TERM MONITORING

A two-stage program for the vegetation related AQRV's will provide adequate monitoring of air pollution impacts. The first stage utilizes the most sensitive plant species to alert the land manager that air pollutants are reaching the wilderness in potentially significant quantities. While the biological significance of impacts to these sensitive species may not be understood, their importance to the monitoring program is that they trigger the second stage. The land manager will have to make a decision regarding the action to be taken should the sensitive monitors begin showing responses to air pollution.

The second stage of the monitoring program involves collecting data from important species in each of the five major vegetation types. These species will be selected based upon their ecological importance or their value in influencing the uses of each of the vegetation types. As examples, Englemann spruce will be monitored because

Table 5.--Vegetation AQRV's indicator species matrix: summary of what to look for, what is not known, and indicator responses to air pollutants[a]

Vegetation type	Ozone		Sulfur dioxide	
	Upland	Lowland	Upland	Lowland
Conifers	Engelmann spruce 1,2,4	Lodgepole pine 1,2,4	(Lichens) 1,5,3	?
Mixed grassland	?	Agropyron sp. Koeleria sp. Poa sp. Response 1,3,5		--
Riparian shrubs	?	?	?	
Aspen	1,4	1,4	1,4	1,4
Marshes	?	Duckweed (?) 6	?	?

[a]Indicator responses to air pollutants:

1. Visible injury symptoms on leaves (e.g., O_3 flecking).
2. Reduced pine needle retention (e.g., "tufted" branches on ponderosa pine).
3. Sulfur concentration in leaves (once baseline is established).
4. Reduced tree ring increments.
5. Reduced species population abundance and distribution.

of its importance as one of the dominants in the spruce-fir vegetation type, while parry clover will be monitored in grassland type because of its importance as a forage species and its importance as a potential nitrogen fixer.

An important basis for adopting this approach is the low probability of impacts if the Class I PSD increments are not exceeded. One major concern, however, is with inadequate information about potentially high concentrations of ozone (O_3) over the wilderness area. There is currently nothing in the scientific literature that would support the idea of biological effects if the Class I increments for SO_2 are not exceeded.

In addition to use of two stages of biological monitors, it is suggested that in the first stage, two locations be emphasized: the highest elevation sites and sites located in drainages. The valley sites will be closest to areas becoming urbanized in concert with the shale industry. The high-elevation sites should be more vulnerable to air pollutants released through tall stacks from power plants to the north and the oil shale industry to the west.

First-stage Monitors

Exposures of vegetation to air pollutants should be monitored by utilizing the most sensitive plants in the wilderness area (table 6). Lichens and bryophytes are the two plant groups most sensitive to SO_2 exposures. Lichens have been reported to respond to SO_2 concentrations considerably below those to which vascular plants respond (Linzon 1978). Bryophytes also provide a very sensitive monitoring capability for SO_2 (Smith 1981), although they have not been used as

Table 6.--Proposed first-stage biological monitors for impacts of air pollutants on the vegetation of the Flat Tops Wilderness area

Pollutant	Landscape positions	
	High elevation	Valleys
Sulfur dioxide	Lichens in spruce and fir trees	Lichens in ponderosa or lodgepole pine and aspen
	Lichens on soil surface and rocks in grassland	Bryophytes
	Bryophytes	
Ozone	Needle retention in spruce and fir	Needle retention in ponderosa or lodgepole pine

widely as lichens. Since the sensitivity of lichens and bryophytes to ozone is not as well established, monitoring of needle retention in the conifers has been proposed. Needle retention in many conifers has been reported to be quite sensitive to exposure to oxidant air pollution (Miller and McBride 1975).

Based upon the results of a botanical survey of the Flat Tops, species of lichens should be selected from the spruce-fir forested areas and the grasslands as SO_2 exposure monitors. In the forest, these should be on the epiphytic lichens. In the grasslands, a species growing on the soil surface should be used; in the highest areas, lichens growing on rocks; and in the drainages, epiphytic lichens associated with aspen and pines.

At the high-elevation locations, needle retention in Englemann spruce should be used to monitor exposures to ozone. In valleys, similar assessments of ponderosa pine and/or lodgepole pine should be made.

Second-stage Monitors

The species utilized in this part of the program should be selected by criteria other than their known response to air pollutants (table 7). The concern here is with potential impacts of direct significance to the integrity and uses of the wilderness area. For SO_2, the sulfur content in the leaf tissues of important species in each vegetation type was selected despite our awareness that the effects of a change in the sulfur content of a plant as a result of exposure to SO_2 are not always easily interpreted. Sulfur content is often one of the first items altered as a result of SO_2 exposure.

Ozone exposure may be more difficult to document on a variety of species. Because exposure of a plant to O_3 often leaves no symptoms except tissue death, we have proposed utilizing visible leaf injury to important species as the indicator of O_3 exposure.

A response indicating air pollution exposure by one or more of the second-stage monitors should trigger additional investigations that could be of more direct ecological significance. They would include such things as increment borings to determine growth rates, biomass and density estimates of trees, species composition and productivity of grasslands and marshes, and growth rates and density of riparian shrubs.

PREDICTION OF AIR POLLUTION IMPACTS

As time series data are available for pollutant concentrations, ecological simulation models may provide a capability for predicting ecological impacts based upon the newest and most sophisticated effects data available. Simulations can be accomplished much less expensively than field sampling, and new information can be incorporated into the model rapidly. The limitations to using ecological simulator models are similar to those of meteorological dispersion models.

Sampling Design

Selection of sampling areas within the wilderness area should be a reflection of expected air quality gradients. A grid system of sampling stations should provide a selection of sites that reflect the variability of air quality in the wilderness. Ten to 30 sampling stations will provide a reasonable array of sampling stations. The logistic and economic factors will be major determinants of the number of sampling stations selected. Sampling stations should be selected so that edaphic, topographic, and micrometeorological variation among them is minimized. At each sampling station, a minimum of 10 subsamples should be selected for each characteristic to be monitored (e.g., arboreal lichen densities or

Table 7.--Proposed second stage biological monitors for impacts of air pollution on the vegetation of the Flat Tops Wilderness

Vegetation type	Pollutant: Sulfur dioxide	Pollutant: Ozone
Coniferous forest	Sulfur content of spruce and fir needles	Needle retention in spruce
Grassland	Sulfur content in foliage of tufted hairgrass and willow	Visible leaf injury to parry clover
Riparian	Sulfur content in willow leaves	Visible leaf injury to aspen
Aspen	Sulfur content in foliage of aspen and Canada wild rye	Visible leaf injury to aspen
Marsh	Sulfur content in tall larkspur	Visible injury to tall larkspur

sulfur content of aspen leaves). It is probably more important to pare down the number of sample areas selected in order to maintain a sufficient number of subsamples to provide reasonable estimates of statistical parameters. An annual sampling scheme should be sufficient to identify responses to changes in air quality.

Data Collection

Exposure monitoring.--Lichens are expected to be the most sensitive indicators of SO_2 dosages on the wilderness area. In the forested habitats, arboreal lichens are expected to be the primary monitoring indicators. At each station, at least 10 trees can be selected, and density of lichens per tree can be determined for each sampling period. Crustose lichen densities can be estimated from 10 or more selected quadrants on rock or soil substrates. Differential changes in densities of lichens among sample stations will reflect differential environmental factors affecting the station site.

Ozone effects may be best reflected in conifer needle retention. At each sample station, a number of branches from at least 10 selected individual trees can be examined to estimate the average number of needle bundles per branch. Differences in the rate of needle retention from year to year among sample stations will reflect differential environmental factors affecting station sites.

Effects monitoring.--In order to monitor effects to local vegetation communities, plant tissue sulfur content has been selected as an indicator of SO_2 effects, and visible leaf injury as an indicator of O_3 effects. Leaf tissue samples of each indicator species can be collected at each sampling station and returned to the laboratory for chemical analysis. Increasing tissue sulfur contents with time and exposure intensity will indicate incipient SO_2 effects upon the local biota. Increasing frequency of observable leaf damage with time would be indicative of incipient ozone damage to the local vegetation communities.

Data Analysis

Leaf tissue can be dried and sent to an analytical laboratory for standard chemical determination of sulfur content.

Records of observation of needle retention, lichen densities, and leaf damage frequencies should be recorded in such a manner as to be readily extracted for statistical analyses. The numbers can be analyzed by standard statistical methods (including analysis of variance) to detect any differences among sampling stations.

Interpretation

Differences among sampling stations may be interpreted as being due to changes in air quality if one can demonstrate that air quality variation is the dominant independent variable among the stations. The confidence that one will have in such an interpretation is an inverse function of the variance of other independent environmental variables that characterize the stations.

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5. AIR QUALITY SIMULATION MODELING

R. Drake, D. Fox, and J. Carson

INTRODUCTION

Objectives

The objectives provided to the modeling group were:

1. Review modeling currently available.
   a. Develop a listing of all ongoing modeling relevant to western Colorado (SAI/EPA, LASL/NCAQ, DOE/Argonne-Battelle) (see appendix B).
   b. List concentration projections for the Flat Tops Wilderness area for different levels of industrial development.
   c. Critique the various modeling exercises.
2. Review the adequacy of current modeling from the perspective of evaluating air quality related values (AQRV's) on the Flat Tops Wilderness.
3. Develop plans to identify what should be done to bridge any gaps between the modeling that is available and modeling needed.

Need for Modeling

An air quality simulation model is a quantitative method, based on physical principles, used to estimate pollutant concentrations in a specific area and period of time. Concentrations are dependent on at least two major factors: (1) the location, nature, and magnitude of emissions and (2) the meteorological conditions to which the emissions are subjected as they are transported, possibly transformed chemically, and diffused. The Clean Air Act and subsequent regulations require the use of air quality simulation models to estimate the concentration resulting from new sources. In particular, the contribution of a new source to existing concentrations of criteria pollutants cannot cause any exceedance of the National Ambient Air Quality Standards (NAAQS), or of any state ambient standard. The criteria pollutants are SO_2, PM, CO, O_3, NO_x, NMHC, and Pb.

Locations where the NAAQS's are currently being met are designated Prevention of Significant Deterioration (PSD) areas and classified as either Class I (the most protected areas, which include most national parks and wilderness areas that existed prior to August 7, 1977, as well as any other areas designated by the state); Class II (virtually all the remaining land); or Class III (a designation allowing greater development than Class II). The Flat Tops is a mandatory Class I area (established by the 1977 Amendments to the Clean Air Act), while all the surrounding areas currently are Class II. In Class II areas, there are annual, 24-hour, and 3-hour average increments of SO_2 and PM concentrations that accumulate with each new permitted source until a particular level is attained. If, in a Class II area, the increment is calculated (by a model) to cause the level to be exceeded, the facility cannot be permitted; it then becomes necessary to consider either a greater level of emission control, relocation, offsets, or, perhaps, an improved model and a field study to validate it. While there are also Class I increments, they serve more as a guide to the determination of any adverse impact on AQRV's (including visibility) of the Class I area, than to an absolute "yes/no" decision. Although the increments apply only to PM and SO_2, AQRV's are to be protected against all pollutants. This protection is afforded through the affirmative responsibility of the federal land manager (40 CFR 52.21(q)).

There are three basic outputs for adequate air quality modeling: (1) point values of ground level maximum concentrations of pollutants that have NAAQS or state AAQS, and of SO_2 and PM increments for PSD (regulatory modeling); (2) concentration distributions aloft of appropriate chemical constitutents (e.g., PM, SO_x, sulfates, nitrates), to determine visibility impairment within the Class I area and along any integral vistas prómulgated by the state (40 CFR 51.304); and (3) distribution of chemical materials (e.g., SO_2, PM, sulfate nitrate, NO_x, O_x, heavy metals), deposited, especially to the Class I areas, which could be expected to cause an adverse impact to AQRV's. These requirements call for concentration estimates on time scales ranging from 1 hour up to 1 year. The modeling required is illustrated in figure 3 (see p. 5).

MODELING ACTIVITIES

This listing of modeling activities is broken down between operational and research activities. While EPA air quality regulations require operational modeling estimates, it is generally recognized that these estimates are in need of refinement (Fox and Fairobent 1981). At the present time, EPA has no "recommended" model for application in complex topographic locations such as western Colorado. This results in the use of a recommended "screening" technique (the so-called "valley" model) by default. Screening techniques

are characterized as conservative, first-cut approximations. The use of such techniques may very well lead to premature and incorrect increment consumption. Recently, a set of statistical procedures has been developed to quantify comparisons of predictors from an air quality simulation model and observations (Fox 1981). The EPA is adopting these procedures for use in evaluating a new model and allowing its use for regulatory decisons.[6] This procedure calls for an extensive, site-specific field study to develop the data necessary to conduct this evaluation. Thus, modeling that is now categorized as research may very well become operational for PSD permitting in the next few years. Model development research is being conducted primarily by EPA- and DOE-supported National laboratories, while the federal land managers, universities, and some consulting companies are also involved. Application of models is done by all these groups and more. Discussions regarding the accuracy of modeling are included in the above references.

Operational Modeling

1. Colony Oil Shale Project--Near-Source Model

   A comparison of valley and plateau location of a plant in Parachute Creek drainage through the use of a Gaussian plume model, with dispersion coefficients modified by field tracer data.

2. Various Developers--Preliminary Modeling Results

   Results determined long- and short-term ground level concentrations from various unit operation scenarios using the EPA valley model and box models of one sort or another to account for limited mixing effects, rough terrain, and stagnation episodes.

   Some developers have used other varieties of Gaussian plume models for near-source and mesoscale transport. Most of these activities are referenced in an Office of Technology Assessment (1980) report.

3. EPA/Denver Research Institute--Assessment Models

   Results from a study by Systems Applications, Inc., using (a) modified Gaussian valley model to calculate SO_2 and PM maximum concentrations near the sources, and (b) a reactive plume model to determine long-term regional impacts on ambient NO_x, O_3, SO_2, PM, and visibility.

4. NCAQ/Los Alamos National Laboratory--Impact Modeling

   A modified Gaussian approach using suggestions recommended by the National Commission on Air Quality (Fox and Fairobent 1981) to estimate increment consumption by shale developments. In addition, visibility calculations for surrounding Class I areas are presented.

Research Modeling

5. EPA/University of Minnesota--Simple Aerosol Model

   This is not oil shale oriented, but may be used as a simple module for particle/particle interactions.

6. EPA/RTP--Regional Oxidant Model

   A regional scale model is under development primarily for application to the northeastern United States oxidant (O_x) problem by EPA in Research Triangle Park, N.C. (RTP). This model probably will not be easily adapted to oil shale applications.

7. EPA/ERT--Complex Terrain Model

   A point-source, complex terrain, model development and evaluation effort is being conducted for EPA by Environmental Research and Technology, Inc. This effort will result with a replacement for the EPA valley model within the next five years. It should see major applications in the shale region.

8. EPA Region VIII/Systems Applications, Inc.--Regional Model

   Model developed for high plains coal assessment--may be modified for oil shale, but only with significantly higher funding than now available.

9. EPA Headquarters/BATTELLE Northwest Laboratories--Mesoscale/Local

   A grouping of models on various scales for application to the oil shale region, including the following:

   a. Regional flow model--This model provides wind profiles needed to run a mesoscale, mass-consistent, wind field model.

   b. Mesoscale flow model--A mass-consistent wind field model that is terrain-following and accommodate variable densities.

   c. Mesoscale air quality model--This model is under development based on the Lagrangian Puff approach accounting for wet/dry removal and coupling/decoupling with local flows. It will be designed to accept reaction, aerosol, and visibility modules developed by others.

[6]Interim proceedings for evaluating air quality models. 64 p. An unpublished report by Environmental Protection Agency, OAQPS, SRAB, Research Triangle Park, N.C., 1981.

d. Local scale flow and air quality models --An analytical model to simulate radiation-driven growth of the convective boundary layer (CBL) in mountainous terrain coupled to a sector-averaged, analytical, air quality model has been developed. It will be used to estimate the time period of coupled/decoupled flows that will provide coupling coefficients for the mesoscale air quality model.

10. USDA Forest Service/CSU--Planning Models

The topographic air pollution analysis system (TAPAS), including the following:

a. A diagnostic, two-dimensional wind field model (WINDS) (Fosberg et al. 1976).

b. A Lagrangian puff dispersion model including plume rise, dispersion, and terrain corrections.

c. A local box model with variable mixing depth for application to community area sources (Howard and Fox 1979).

d. An estimate of pollution potential through a simple dispersion model which is useful for planning purposes (Fox and Fosberg 1977).

11. EPA Headquarters/Systems Applications, Inc. --General Policy Alternatives

Gaussian and ventilated box models are used to study management alternatives available for western Colorado.

12. USDI BLM/Systems Application, Inc.--Regional Modeling Assessment

Conduct of a regional modeling exercise to aid in oil shale leasing for Utah and Colorado State areas.

SELECTED MODELING RESULTS FOR FLAT TOPS

1. EPA--Valley-type Calculations

a. Office of Technnology Assessment (1980) projections

(1) 65,000-bpd industry, wind blowing toward Flat Tops, gave 20% of Class II 24-h PSD increment for PM and 33% PSD increment for SO_2, which when scaled up leads to a 217,000-bpd limit on SO_2 and a 325,000-bpd limit on PM.

b. EPA--Region VIII assessment[7]

(1) 1976 prototype lease evaluations for 200,000-bpd total production were estimated to yield the following 24-h average values:

Area	TSP	SO_2
	---($\mu g/m^3$)---	
Dinosaur National Monument	18	5
Colorado National Monument	<3	<1
White River National Forest	8	<2
Ashley National Forest	5	1

(2) PSD permits issued on the basis of this modeling through 1979 will accommodate 62,000-bpd production with an associated Flat Tops impact of 1.5 $\mu g/m^3$ for 24-h average SO_2 and 2.0 $\mu g/m^3$ for 24-h average PM. Scaling this up to the Class I increment suggests a limitation of 207,000 bpd by the SO_2 increment and 310,000 bpd by the PM increment.

2. EPA--Box model type calculations[7]

Assumptions made in this calculation included (a) a single box, 40 km wide, with a variable height of inversion; (b) "Colony type" emissions; (c) no chemical transformation of any emissions; (d) no deposition; (e) no dispersion out of box; and (f) homogeneous mixing of pollutants throughout the box instantaneously.

For the maximum 24-h average impact at the Flat Tops Wilderness, results were estimated using the assumed mixing heights and wind speeds shown at the following values:

Mixing height	Wind speed	TSP	SO_2
(m)	(mps)	---($\mu g/m^3$)---	
2,500	6	0.4	0.5
1,000	5	1.3	1.6
500	5	2.6	3.2
500	3	4.4	5.4
400	4	4.1	5.0

3. EPA estimates based on PSD permitted emission rates[7]

Permitted emission rates as a function of oil production levels (pounds

[7]Paper given by T. L. Thoem at Brown Palace Hotel, Denver, Colo., June 19-20, 1980. Entitled EPA and oil shale.

per barrel of oil) from four PSD permits that have been issued are summarized as follows:

Pollutant	Colony	Union	Cathedral Bluffs	Rio Blanco
SO_2	0.164	0.237	0.160	0.668
NO_x	0.903	0.291	--	--
HC	0.158	0.125	--	--
PM	0.134	0.102	--	--
CO	0.036	0.172	--	--

4. EPA--comparison of impacts of oil shale (Colony permitted emissions) versus power plants (tons per year)

Pollutant	50,000 bpd	1,000 MW power plant
SO_2	1,239	13,790
PM	1,008	1,062
NO_x	6,817	17,714

5. Systems Applications, Inc., and NCAQ/LASL

Both the SAI (Anderson et al. 1980) and the NCAQ/LASL (Williams and Mangeng 1980) modeling exercises use a modified Gaussian valley type dispersion model. Results are listed in table 8.

VARIATIONS IN MODEL ESTIMATES

Differences in the numbers presented in table 8 are caused by four factors:

1. Different emission factors and magnitudes--some studies account for fugitive emissions and some do not. There is great uncertainty in the emissions from the oil shale projects because they are only prototypes with emission control equipment not yet determined.

2. Use of different, and sometimes contradictory, spatially uniform winds. There is insufficient information to know if measured winds are representative of the entire area. The meteorology of the region must be better characterized.

3. Different assumptions regarding plume rise and its interactions between mixing heights and atmospheric stability are made within models. Data specifying stability and mixing height are not uniformly treated and may not be representative--again the meteorology must be better characterized.

4. Different assumptions on diffusion coefficients removal processes and other model parameters are made in models--agreement on acceptable models and modeling technology is being sought but should be more strongly encouraged.

ADEQUACY OF MODELING FOR AQRV ANALYSIS

The modeling that has been done so far is totally inadequate to evaluate impacts on air quality related values (AQRV's) of the Flat Tops Wilderness. Reference is made here to figure 3 (p. 5), which illustrates that a rather complex array of modeling must be developed in order to assess impacts on the Flat Tops Wilderness in a rational manner.

The modeling displayed in this section is regulatory modeling. It is done to identify acceptable levels of development. The examples shown are often large, generalized assessments and not necessarily as accurate as is possible. The emissions data and the meteorology used by the models are gross approximations of what actually might occur. The models themselves are either

Table 8.--Flat Tops concentrations resulting from modeling exercises

Pollutant	Appropriate standard	1995 SAI 880,900 bpd	1995 NCAQ/LASL 939,000 bpd
SO_2	($\mu g/m^3$)		
3-h	25	12	21
24-h	5	--	5.1
Annual	2	--	0.3
PM	($\mu g/m^3$)		
24-h	10	7	3.6
Annual	5	--	0.2
O_x	(ppm)		
1-h	0.12	0.106	
NO_x	(ppm)		
Annual	0.05	0.002	

designed or degraded to produce only a single worst-case number for concentration at a point. This modeling is most appropriately interpreted as an index required by law and regulation in order to determine how much development will be allowed. This approach could have been used to protect Class I areas; in fact, the Class I increment concept is a representation of it. However, Congress enforced this approach by providing federal land managers with a more substantive responsibility; namely, an identification of impacts on Class I areas and a determination of the potential adversity of those impacts. In order to accomplish this, the federal land manager must consider the pollution field that is deposited over an extended time period; namely, the dosage that results to various receptors in the Class I area. Considerably more sophisticated modeling is needed to accomplish this, and a substantial effort will be needed to evaluate the effects of these projections of AQRV's.

NEEDS FOR ATMOSPHERIC DISPERSION MODELING TO ASSESS AQRV IMPACTS

Basically there are needs to (a) improve the air quality models for application to multiple sources in complex topography (this will require enhanced fundamental knowledge in mountain meteorology), (b) provide the data (emissions and meteorology) required for operational application of the models, and (c) conduct performance evaluations to establish the validity of these models. Here we focus on the data needs, with only passing reference to model development/mountain meteorology research and performance evaluation needs.

In order to utilize models, we will need to improve quantification of the following:

A. Atmospheric emissions of various chemicals

1. Pollutants for which NAAQS's have been established: SO_2, PM, CO, O_3, Pb, NO, NMHC.

2. Currently unregulated pollutants: silica, other sulfur compounds, metals, CO_2, NH_3, trace organics, trace elements (e.g., Be, Hg, asbestos, F), and respirable particles and anything else identified as possibly contributing to an adverse AQRV impact.

B. Emissions on the basis of facility unit operations (emission factors)

1. Mining: silica, salts, mercury, lead, methane, CO, NO_x, HC, PM, fugitive dust.

2. Storage, transport, and crushing of oil shale: PM, CO, NO_x, SO_2, HC, silica, fugitive dust.

3. Retorting technologies: SO_2, H_2S, COS, NO_x, HC, CO, POM, PM, trace elements and heavy metals (i.e., antimony, arsenic, beryllium, boron, copper, fluorine, lead, mercury, nickel, selenium, zinc, cobalt, molybdenum, chromium, iron).

4. Upgrading, refining, gas cleaning, and power generation: CS_2, COS, SO_2, H_2S, NH_3, HC, NO_x, fly ash.

5. Handling and disposal of raw and retorted shale: fugitive dust, POM.

6. Community growth, generally offsite, including space heating stationary sources, and mobile sources like automobiles and trucks: NO_x, PM, RHC, CO, POM.

C. Characteristic of the emission in detail

1. Locations of facilities and operations.

2. Size of activities, quantity and time histories of emitted material as a function of the type of process.

3. Local meteorological conditions: as a function of time and space, wind vector fields, atmospheric stability, topography, local precipitation, etc.

4. Physical parameters of the sources including temperature of effluent, velocity of effluent, stack heights, etc.

5. Background concentrations of air pollutants and chemical precursors.

D. Surface characteristics of areas where concentration estimates are required

1. Location and terrain features and surface details (forest canopy cover) of all target and receptor areas in relation to the source areas.

2. Terrain and surface conditions between the source and such target areas.

3. Location and air quality impacts from any other sources that may affect the target areas (contributions to the background pollutants of the target areas).

E. Meteorological conditions

1. Wind speed and direction fields through the zone of atmospheric transport from sources to target areas.

2. Routine release of radiosonde and/or pilot balloons at a sufficient number of locations within the development/transport area to characterize the synoptic climatology.

3. Atmospheric stability structure fields between sources to target areas.

4. Cloud cover and precipitation fields from sources to target areas.

5. Diurnal and seasonal variations of solar radiation and surface energy budget fields between sources and target areas.

6. Identification of any special or different local phenomena that might influence transport, dispersion, and removal.

In order to project dosages to the Flat Tops accurately, models must be able to account for physical processes that affect the concentration and dilution of pollutants. Some of the things that need to be considered are shown:

1. The characteristics of temperature inversions within the convective boundary layer, including their frequency of occurrence, extent, and nature, and the mechanisms by which they are formed and destroyed.

2. An understanding of how local valley circulations form, dissipate, and become coupled or decoupled from the synoptic-level flows.

3. An understanding of dry and wet deposition processes; in particular, the distribution of dosage as a function of forest canopy parameters such as tree sizes, spacing and densities, and species composition.

4. How simple a coupled meteorological/dispersion/deposition model can be to simulate adequately the transport, diffusion, and deposition of pollution from multiple sources to the Flat Tops Wilderness.

This list is by no means comprehensive, but it does point to some of the difficulties in modeling in the oil shale areas.

CONCLUSIONS

Current projections based upon reasonably high levels of oil shale production indicate that PSD Class II increments as well as Class I increments will need to be carefully investigated for each proposed facility as well as for the totality of the development. Individual facilities will require careful planning and some strong emission control before the Class II increment will be met.

Unfortunately, there is no fully acceptable analysis of the actual impact, namely concentrations and dosages, on the Flat Tops Wilderness area as a result of oil shale development. This is a difficult problem that is only now beginning to receive attention. Complication is added not only by the recognized problems of dispersion modeling on 100-km scales in mountainous topography, but also by equally difficult problems involving plume interaction with forested surfaces, and precipitation. Work is needed immediately to make preliminary identifications of pollutant concentrations and dosages likely to occur on the Flat Tops Wilderness as a result of the combination of industrial and community growth associated with the development of an oil shale industry in western Colorado. Of particular concern is the need to develop improved coordination among federal agencies and developers to conduct this work. The problem is larger than any one agency, leading us to conclude that such coordination is essential and should be a high priority.

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APPENDIX A

LIST OF ATTENDEES

Dr. James Bennett
Air Pollution Effects Specialist/Air Team
USDI/National Park Service
655 Parfet St.
P.O. Box 25287
Denver, CO 80225

Dr. James O. Blankenship
National Air Management Officer
USDA Forest Service
240 West Prospect Street
Ft. Collins, CO 80526

Dr. James Carson
Research Meteorologist
Argonne National Laboratories
9700 S. Cass
Argonne, IL 90439

Dr. Ronald L. Drake
Research Meteorologist
Battelle-Northwest Laboratory
Atmospheric Science Dept.
Box 999
Rickland, WA 99352

R. Scott Fifer
Hydrologist
USDA Forest Service
White River National Forest
Box 948
Glenwood Springs, CO 81601

Dr. Douglas G. Fox
Research Meteorologist
USDA Forest Service
Rocky Mountain Forest and
Range Experiment Station
240 West Prospect Street
Ft. Collins, CO 80526

Dennis Haddow
Regional Air Quality Specialist
USDA Forest Service
11177 W. 8th Avenue
Box 25127
Lakewood, CO 80225

Wendy M. Harrett
Ranger, Blanco District
USDA Forest Service
White River National Forest
Box 948
Glenwood Springs, CO 81601

Lee W. Jensen
Ranger, Yampa District
USDA Forest Service
Routt National Forest
Hunt Building
Steamboat Springs, CO 80477

Douglas A. Latimer
Air Quality Consultant
Systems Applications, Inc.
950 Northgate Drive
San Rafael, CA 94903

Dr. William Malm
Visibility Research Specialist/Air Team
USDI National Park Service
c/o Dept. of Atmospheric Sciences
Colorado State University
Fort Collins, CO 80523

Dr. William Lauenroth
Air Pollution Effects Specialist
Natural Resources Ecology Laboratory
and Range Sciences Dept.
Colorado State University
Fort Collins, CO 80523

James L. Mangan
Ranger, Rifle District
USDA Forest Service
White River National Forest
Box 948
Glenwood Springs, CO 81601

Dr. William E. Marlatt
Professor, Bioclimatology and Air Pollution
Department of Earth Resources
Colorado State University
Ft. Collins, CO 80523

Eric J. Martin
Landscape Architect
USDA Forest Service
White River National Forest
Box 948
Glenwood Springs, CO 81601

Robert J. Miller
Recreation Specialist
USDA Forest Service
White River National Forest
Box 948
Glenwood Springs, CO 81601

Dennis J. Murphy
Air Quality Researcher
Rocky Mountain Forest and Range
Experiment Station
240 West Prospect Street
Fort Collins, CO 80526

Dr. James Newman
Air Pollution Effects Consultant
Environmental Science and
Engineering, Inc.
Box 5
Gainsville, FL 32602

Robert H. Peterson
Botanist, Blanco District
USDA Forest Service
White River National Forest
Box 948
Glenwood Springs, CO 81601

Bernie Rios
Wildlife Biologist
USDA Forest Service
White River National Forest
Box 948
Glenwood Springs, CO 81601

Julie K. Sarazin
Wildife Biologist, Rifle District
USDA Forest Service
White River National Forest
Box 948
Glenwood Springs, CO 81601

Dr. Kent R. Schreiber
Air Pollution Effects Specialist
USDI/Fish and Wildlife Air Pollution Effects
Eastern Energy and Land Use Team
Route 3, Box 44
Kearneysville, WV 25430

Dr. Lars Soholt
Biologist
Environmental Impact Studies
Argonne National Laboratories
9700 S. Cass
Argonne, IL 90439

Larry D. Summers
Botantist, Blanco District
White River National Forest
Box 948
Glenwood Springs, CO 81601

Dr. John Turk
Limnologist
U.S. Geological Survey
WRD, Colorado District
Box 25046, MS415
Denver Federal System
Lakewood, CO 80225

Victor K. Weyers
Forester
USDA Forest Service
White River National Forest
Box 948
Glenwood Springs, CO 81601

Dr. Michael Williams
Air Quality Research Specialist
LASL, Group S-3, MS603
Las Alamos, NM 87545

APPENDIX B

ACRONYMS, ABBREVIATIONS, AND CHEMICALS

ACRONYMS

AAQS - Ambient Air Quality Standards
PSD - Prevention of Significant Deterioration
AQRV - Air Quality Related Values
TSP - Total Suspended Particulates
BACT - Best Available Control Technology
EPA - Environmental Protection Agency
RAWS - Remote Automated Weather Station
SCS - Soil Conservation Service
DOE - Department of Energy
NAAQS - National Ambient Air Quality Standards
ERT - Environmental Research and Technology, Inc.
CBL - Convective Boundary Layer
OTA - Office of Technology Assessment
NE - North East
RTP - Research Triangle Park, NC
DRI - Denver Research Institute
SAI - Systems Applications, Inc.
LASL - Las Alamos Scientific Laboratory
NCAQ - National Committee on Air Quality

ABBREVIATIONS

MW - Megawatt (10^6 watt)
tds - total dissolved solids
cfs - cubic feet per second
m - meters
km - kilometers
bpd - barrels per day
mps - meters per second

CHEMICALS

S - Sulfur
SO_2 - Sulfur dioxide
O_3 - Ozone
CO_3 - Carbonates
HCO_3 - Bicarbonates
$CaCO_3$ - Limestone
B - Boron
Mo - Molybdenum
As - Arsenic
P - Phosphous
N - Nitrogen
F - Fluorine
HC - Hydrocarbons
PM - Particulate Matter
CO - Carbon monoxide
NO_x - Nitrogen oxides (NO, NO_2)
POM - Polycyclic Organic Material
NMHC - Non-methane hydrocarbons
Pb - Lead
SO_x - Sulfur oxides
O_x - Oxidants
pb - Lead
NH_3 - Ammonium
Be - Beryllium
Hg - Mercury
H_2S - Hydrogen sulfide
COS - Carbonyl sulfide

Fox, Douglas G., Dennis J. Murphy, and Dennis Haddow. 1981. Air quality, oil shale, and wilderness--A workshop to identify and protect air quality related values of the Flat Tops. USDA Forest Service General Technical Report RM-91, 32 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

In January 1981, a workshop was conducted to discuss the potential impacts of oil shale developments on the air quality of western Colorado. Participants of the workshop included nationally recognized specialists in air quality modeling, in visibility, and in effects of air pollution on soil and water, fish and wildlife, and vegetation. The five working group reports that resulted outline an ambitious program of research necessary in order to protect the Flat Tops Wilderness. The workshop illustrates a general approach to the problem of identifying air quality related values. It is anticipated that this approach will prove useful to all federal land managers involved with Class I area protection.

Keywords: Air quality related values, air pollution, wilderness

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

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Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526